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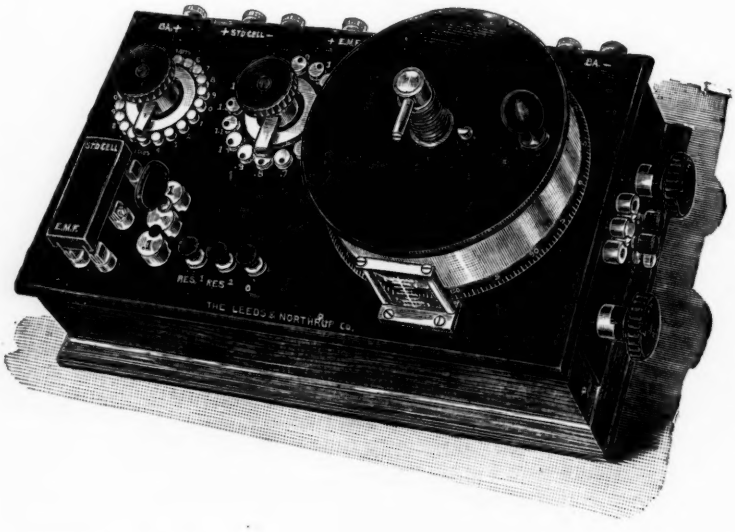

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PHYTOPATHOLOGY

VOLUME VIII NUMBER 7

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HOST RELATIONSHIPS OF THE NORTH AMERICAN RUSTS, OTHER THAN GYMNOSPORANGIUMS, WHICH ATTACK CONIFERS

ARTHUR S. RHOADS, GEORGE G. HEDGCOCK, ELLSWORTH BETHEL, AND CARL HARTLEY

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INTRODUCTION

The conifers have a larger proportion of their parasitic enemies among the rusts than perhaps any other important group of plants, outside of the grasses. Practically all our native gymnosperms, excluding the suborders Cupressineae and Taxineae, are attacked by one or more species of rusts. All of these rusts except three[1] have aecial stages on conifers, and belong

[1] The exceptions are the following autoecious forms: *Gallowaya pini*, *Necium farlowii*, and *Chrysomyxa weirii*.

either to the form genus Peridermium or to Caeoma, according to whether the aecia possess or lack a distinct peridium. It should be borne in mind that the form genera, under which the aecial phases are classified, are rapidly going into disuse since when the telial stage is found the fungus automatically takes this name. The retention of form genera in this paper as designations for the aecial stages is justified only by the convenience of their usage. Where the relationship of the aecial and telial stages of a rust has been established and no prior species has been attached to the form genus, the specific name of the telial stage is used. In the present paper there are included all rusts attacking trees of species belonging to the genera Pinus, Larix, Picea, Tsuga, Pseudotsuga, Abies, and Ephedra.

The work of the American and European investigators has shown that a few of the North American species are synonymous with or are racial forms of certain well known and long recognized species of Europe. The majority of our species, however, are morphologically distinct and strictly American. Some European Peridermiums have already become introduced into North America as a result of our formerly unrestricted practice of importing foreign nursery stock. *Cronartium ribicola*, which attacks the most valuable American pine so vigorously as to threaten its elimination from the commercial field, was introduced on white pine and is now established beyond hope of eradication in the Northeastern States and discouragingly common in a part of Minnesota. Whether or not the very valuable *Pinus lambertiana* and *P. monticola* of the West can be kept free from this parasite is a serious question. The economic importance of the pine rusts is further emphasized by the recent damage done by one of our native species. *Cronartium comptoniae*, native on eastern pines, has been shown by its work on western pines introduced into the East to be an amazingly destructive parasite on them, probably sufficiently so as to prevent their being of commercial value in any locality where the alternate host is common. The need of keeping this rust out of the Pacific Northwest is, therefore, emphasized. For like reasons, *Cronartium filamentosum* and *Cronartium pyriforme* should not be introduced into new regions, since both have been found destructive to young pines of a number of species.

In general it may be said that the majority of the known Peridermiums and their related forms occur in the northern hemisphere. Their aecial stages are generally known from a much more limited habitat than their corresponding uredinial and telial stages. The evidence afforded by recent investigations has shown that several species of forest tree rust may propagate themselves, in the uredinial stage, through the winter upon the rosettes and other perennial plant parts by means of the myce-

lium and urediniospores. As was pointed out by Ludwig (89), these rusts appear to maintain a high degree of vitality for a long period without sexual reproduction. The following coniferous rusts are known to winter over in living parts of their alternate (dicotyledonous) hosts: *Cronartium cerebrum, Coleosporium elephantopodis, C. ipomoeae, C. helianthi, C. solidaginis, C. terebinthinaceae, C. vernoniae, Melampsora bigelowii, Melampsorella elatina, Melampsoridium betulae, Melampsoropsis Cassandrae, M. pyrolae,* and *Pucciniastrum pustulatum.* There is also a strong probability that *Coleosporium ribicola, Cronartium ribicola,* and *Cronartium occidentale,* winter over on Ribes, and that *Cronartium pyriforme* winters over on Comandra. By reason of being independent of aecial infection and spreading by urediniospores, some of these rusts are often found at great distances from their aecial hosts. Owing to its habit of overwintering in the uredinial and telial host, *Melampsora bigelowii* may occur on species of willow where the aecial host may be a thousand miles distant.

Our coniferous rusts, exclusive of Gymnosporangium, are distributed among at least twelve telial genera. Of these, Calyptospora, Coleosporium, Cronartium, Melampsora, Melampsorella, Melampsoridium, Melampsoropsis, Pucciniastrum, and Uredinopsis are heteroecious. The remaining three genera are autoecious and are represented by *Chrysomyxa weirii, Gallowaya pini,* and *Necium farlowii,* of which the last two genera are monotypic. Our present knowledge of the genetic relationship of this group of rusts has resulted in the development of a number of common characters, the use of which aids greatly in the search for the alternate stage. It will be noted that the Coleosporiums are related to the foliicolous Peridermiums on Pinus; Cronartiums to caulicolous Peridermiums on Pinus; Melampsoras to Caeomas on leaves of Abies, Larix, Pseudotsuga, and Tsuga; Melampsorellas to Peridermiums forming "witches' brooms" on Abies and Picea; Melampsoridium to Peridermium on leaves of Larix; Melampsoropsis to Peridermiums on leaves and cones of Picea; Pucciniastrums to Peridermiums on leaves of Abies, Tsuga and Picea; and the uredinopsis rusts of ferns to Peridermiums on leaves of Abies. This general theory for the assignment of certain form-species to their telial genera holds for all the species of the groups mentioned whose connections are known, and will presumably continue to hold for other species.

In a similar way generalization can be made for the telial genera in regard to the time of germination of their sporidia and subsequent infection of their hosts. The teliospores of the Coleosporiums, Cronartiums, and Uredinopsis germinate at maturity and infection ensues at once. In the Coleosporiums the pycnia appear in early winter and the aecia will be found the following spring on pine needles one or more

years old. In the Cronartiums the pycnia appear in one or more years, and are followed by aecia the succeeding year. In most other telial genera the teliospores require a resting period over winter and germinate in the spring; the aecia produced therefrom usually appear only on the leaves or cones of the same season's growth. In the stem-inhabiting Peridermiums on pine, as well as in the broom-forming rusts on Abies and Picea, the mycelium of the fungus is perennial; in one of the cone rusts on Pinus it is perhaps biennial. None of the other rusts considered here, except possibly *Peridermium ephedrae*, are known to have mycelium perennial in their aecial hosts so that infection, when present, must occur anew each year.

Stem rusts like the white pine blister rust, instead of being localized and forming galls, are not limited in the area they attack. A single lesion on a small twig or branch may extend to the trunk and ultimately cause the death of the whole tree. In general it may be said that the leaf-and cone-inhabiting forms are of less economic importance, since they do not affect the vital parts and do not commonly become so abundant as to cause marked defoliation or diminution of seed production.

The identification of the aecial stages attacking leaves of conifers is difficult owing to the fact that the greater part of them develop spore-structures, which, although they resemble one another closely, are genetically connected with the teleutosporic fungi of quite different species. In recent years the inherent difficulties attendant upon the delineation of the species, largely due to the slight morphological differences existing between many of them, have been lessened since the microscopic characters have been liberally supplemented by cultures. We are beginning to attach less reliance to the use of spore measurements in separating species and place more emphasis on the host relationships exhibited. As a result of this several species that formerly were considered to be distinct are now combined into a single species or at least recognized as racial forms of the same species. As a matter of fact, in most cases involving heteroecious rusts, successful inoculation under controlled conditions is considered very necessary in determining the identity of the species under consideration, not only from the aecial to the telial host, but often from the telial to the aecial in addition.

It will be noted that certain closely related rusts, whose aecial stages are apparently distinct, have uredinia and telia which are not easily differentiated. The following partial list of Peridermiums showing pairs which have very similar telia on the same hosts is of biological significance:

Peridermium occidentale
Peridermium strobi } Cronartium on Ribes and Grossularia.

Peridermium fusiforme, *Peridermium cerebrum* } Cronartium on Quercus.

Peridermium harknessii, *Peridermium filamentosum* } Cronartium on Castilleja, Orthocarpus and Pedicularis.

Peridermium coloradense, *Peridermium elatinum* } Melampsorella on Alsine, Cerastium, and Stellaria.

Peridermium acicolum, *Peridermium montanum* } Coleosporium on Aster, and Solidago.

Of recent years numerous experiments have been made with artificial cultures of Peridermiums and related forms, so that the genetic relationships of most of our species have been carefully checked up by a study of their life histories, and the majority of the connections have been made. A number of forms, however, still remain to have their alternate hosts determined. Moreover, it is quite likely that additional species will be described from Mexico and Central America, since this region is less known botanically than any other in North America. On the other hand several of the species as now accepted may not be true species in the restricted sense of the term, but are identical with one another except for host specialization, and by some will be more properly considered as biological races. In some genera, Uredinopsis for example, the presence of bridging hosts shows the very close relationship or practical identity of forms hitherto considered distinct species. Such being the case, we may expect that further cross inoculation work will reduce the number of recognized species. Of the 79 telial species of rusts, as here considered related to or suspected of being related to the North American conifers, but approximately one-half have been connected with their alternate stages.

A vast amount of information has accumulated since the treatment of the rusts in the North American Flora by Arthur (11), and the monographs on Peridermium by Arthur and Kern in 1906 and 1914 (20, 22), most of which has been contributed in fragmentary bits. Moreover, culture work by a large number of investigators has established such a complex of host relationships that it has become practically impossible for any one not a specialist in the group to straighten out the tangle from the literature now available without a tremendous amount of work. Especially in the case of the pine rusts, the number of known species and their hosts has been greatly increased in recent years, and the genetic relationships which have been demonstrated with the uredinial and telial

stages on angiospermous plants have established a network which is almost impossible to grasp unless the entire group be brought together in a compact form.

Some time ago, Hartley, in connection with sanitation work the in neighborhood of forest nurseries, found it necessary to tabulate these rusts and their host relationships as a basis for practical prophylactic work. So many workers desired copies of this table that it was believed that something of the sort should be published. The original table was revised and brought up to date by Rhoads in 1917, with the addition of literature references and an index to the hosts, and is now further revised and augmented with hitherto unpublished data by Hedgcock and Bethel.

In preparing this paper the writers have attempted to assemble in concise form all available information on the rusts of conifers, other than the Gymnosporangiums. In order to increase the usefulness of the data presented in this table, a reasonably complete bibliography covering the more important publications of North American authors dealing with the description, life history, and genetic relationships of this group of rusts has been appended. The morphological characters of the rust species can be obtained readily from these publications, which are referred to by number. The writers also have had access to a number of unpublished manuscripts and are under obligation to Drs. Meinecke, Weir, and Spaulding, and Mr. Hunt, of the Office of Investigations in Forest Pathology, and to Dr. J. C. Arthur for valuable criticisms and permission to use unpublished data.

Opinions will differ as to the treatment of certain species. The writers have taken a conservative attitude and the specific names used are those which are generally accepted. Other combinations which have been proposed need verification by further culture work.

The Office of Investigations in Forest Pathology solicits specimens and will be pleased to exchange specimens of all the coniferous rusts. It is desired that localities, even for the most common rusts, be reported so that accurate data on distribution may be obtained. Geographic distribution often furnishes a valuable clue for rust relationships and provides a basis for culture work. Ample notes with the collections are most desirable, especially notes on the presence or absence of plants which may serve as alternate hosts. A special effort should be made to obtain clues for the unattached rusts. Careful observations in the field, accompanied by complete notes, will, when supplemented by cultures, add much to our knowledge of a group of rusts which are of great scientific interest and pathological importance.

CRONARTIUM

Aecial stage, Peridermium on stems of Pinus; telial stages, on various dicotyledonous plants.

A. CAUSING PRONOUNCED GALL-LIKE HYPERTROPHY

1. **Cronartium cerebrum** (Peck) Hedgc. & Long, Syn.;—*Uredo quercus* Brond., Am. Auct., *Cronartium quercus* (Brond.) Schröt., *Cronartium quercuum* Miyabe. (8[2] 11; 16; 18; 20; 22; 28; 30; 36; 39; 42; 48; 49; 54; 55; 57; 58; 59; 68; 74; 79; 96; 99; 100; 101; 114; 134; 135; 144; 145).

   Hosts:—

   O and I [= **Peridermium cerebrum** Peck (*Peridermium harknessii* Moore, Am. Auct., *Peridermium mexicanum* Arth. & Kern, *Peridermium globosum* Arth. & Kern, *Peridermium giganteum* Tubeuf)] on the following 2- and 3-needled species of Pinus:

banksiana[3]	gerardiana*	oöcarpa	rigida
clausa	glabra	palustris	sabiniana*
contorta*[4]	heterophylla	patula	serotina
coulteri*	jeffreyi ?	ponderosa*	sylvestris
densiflora*	mayriana*	pungens ?	taeda
echinata	muricata*	radiata	virginiana
edulis*	nigra	resinosa	

   II and III on 29 species of Quercus, 22 of which are known to be natural hosts. Nineteen of these, 7 additional species of Quercus, and *Castanopsis chrysophylla* have been successfully inoculated by Hedgcock (55) Long, and Hunt.

   Distribution:—From Vermont and Florida, west to Minnesota, Kansas, and Texas; in the West, along the Pacific Coast from California to Guatemala. Also in China and Japan.

   Remarks:—Globose galls are caused on pines. Meinecke (96) has reinfected pines by inoculations in wounds with the aeciospores of the California form. He also found that the fungus overwinters in the uredinial stage on the evergreen leaves of oaks in California. Hedgcock, in 1918, found

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[2] Reference is made by number to "Literature cited," pp. 346–352.

[3] The nomenclature for the names of plants used in this paper is as follows: For native trees, various publications of George B. Sudworth of the U. S. Forest Service; for foreign trees, Bailey's Standard Encyclopedia of Horticulture, 1917; for the Grossulariaceae, Coville's "Grossulariaceae" in North American Flora, Vol. 22, 1908; for other plants of the northeastern United States and Canada, Britton and Brown's "Illustrated Flora of the Northern United States, Canada and the British Possessions," 1913; for the southeastern United States, Small's "Flora of the Southeastern United States;" for the Rocky Mountain region, Rydberg's "Flora of the Rocky Mountains and Adjacent Plains;" and for the northwestern United States, Piper and Beattie's "Flora of the Northwest Coast."

[4] The asterisk (*) is used throughout this paper, except in the post index, to denote host species proved susceptible by artificial inoculations. Species not so designated are natural hosts.

the fungus overwintering similarly in Florida. Young pines are either badly stunted or killed. Witches' brooms are occasionally formed on the pines in connection with the galls, especially on *Pinus radiata*.

Shear (114), in 1906 by inoculations proved that *Peridermium cerebrum* is the aecial stage of this fungus. Arthur (8) in 1906 verified Shear's results. Hedgcock (55) in 1911 discovered the pycnial stage. In 1915, and again in 1916, he successfully inoculated *Quercus velutina* with aeciospores from *Pinus radiata* received from Meinecke from Monterey, California. Uredinia and telia of *Cronartium cerebrum* were produced, thereby establishing that the form described as *Peridermium harknessii* on *Pinus radiata* belongs to this species.

Uredo quercus Brond. of Europe, as claimed by Hedgcock and Long (74), has no reported aecial stage nor telial stage of the Cronartium type and is not included in this species. Bethel does not agree with this exclusion. Since most of the collections of *Uredo quercus* were made in almost semi-tropical countries, it has been suggested that in warm countries where it may live over, it may not form telia, or that the telia probably agglutinate as in certain paraphysate rusts. However, telia are often produced on *Quercus* in other tropical countries.

2. **Cronartium fusiforme** (Peck) Hedgc. and Hunt., comb. nov. (18; 20; 22; 68; 74).

Hosts:—

O and I (= **Peridermium fusiforme** Peck) on the following 2- and 3-needled species of Pinus:

contorta*	mayriana*	pinea*	sabiniana*
coulteri*	montana*	ponderosa*	serotina
halepensis*	muricata*	radiata*	taeda
heterophylla	palustris	rigida	

II and III on species of Quercus, 16 of which have been successfully inoculated with the aeciospores of *Peridermium fusiforme* by Hedgcock, Long, and Hunt.

Distribution:—Southeastern and southern United States.

Remarks:—Arthur and Kern (22) in 1913 first proved by inoculations that *Peridermium fusiforme* is the aecial stage of a Cronartium on oaks and assigned it to the preceding species. Hedgcock and Long (74) in 1914 by inoculations verified the work of Arthur and Kern, and asserted that the fusiform type of Peridermium apparently always occurs on 3-needled pines, which assumption has been found by Hedgcock and Hunt to be wrong. From inoculations of 8 species of pines with the Cronartium from *Peridermium cerebrum* they obtained sphaeroid swellings or galls only, and from inoculations of 12 species of pines, some of which were the same species as the preceding, with the Cronartium from *Peridermium fusiforme* they obtained fusiform swellings only. From this it appears that we have here two distinct species, of which the former is designated *Cronartium cerebrum*, and the latter *Cronartium fusiforme*. For this reason *Peridermium fusiforme* is treated separately.

This species is very injurious to pines, causing considerable loss in the southern and southeastern United States, especially to *Pinus taeda*.

3. **Cronartium sp.**? Syn.:—*Cronartium coleosporioides* (Diet. & Holw.) Arth., Am. Auct. (11; 20; 47; 53; 57; 69; 141; 142; 145; 146).

Hosts:—

O and I (= **Peridermium harknessii** Moore, Am. Auct.) on the following 2- and 3-needled species of Pinus:

attenuata	heterophylla*	ponderosa	virginiana*
contorta	jeffreyi	pinea*	
coulteri	mayriana*	radiata	
halepensis*[5]	muricata*	sabiniana	

II and III on species of Castilleja, Orthocarpus, and Pedicularis.

Distribution:—Rocky Mountain and Pacific Coast regions from Canada to Mexico.

Remarks:—Under this species is included the sphaeroid or gall form of Peridermium as the aecial stage of part of the Cronartium on Castilleja, Orthocarpus, and Pedicularis. Bethel in Colorado, from 1909 to 1913, successfully inoculated plants of *Castilleja linearifolia* in the open with aeciospores of this Peridermium. Weir and Hubert (138) in Montana in 1915 successfully inoculated plants of *Castilleja miniata*, under controlled conditions, with aeciospores of the same Peridermium. They also successfully inoculated plants of the same species of Castilleja with aeciospores from both *Peridermium filamentosum* and *P. stalactiforme*, confirming the results of Hedgcock (56) and Meinecke (95). For this reason they conclude that these three Peridermiums are identical because all have their telial stages on *Castilleja*. Hedgcock, Bethel, and Hunt, not being able to find intergrading forms between the gall form, ***P. harknessii***, and the non-gall form, *P. filamentosum* (*P. stalactiforme*), do not agree with this finding, which should, they hold, be backed by proof from telial inoculations on pines. Weir and Hubert (142) in 1917 described the pycnia of this species.

B. NOT CAUSING PRONOUNCED GALLS, AND BUT LITTLE OR NO HYPERTROPHY

4. **Cronartium filamentosum** (Peck) Hedgc. & Long. Syn.;—*Cronartium coleosporioides* (Diet. & Holw.) Arth., Am. Auct. (11; 20; 22; 42; 53; 56; 57; 58; 69; 71; 96; 107; 128; 129; 138; 141).

Hosts:—

O and I [= **Peridermium filamentosum** Peck. (*Peridermium stalactiforme* Arth. & Kern)] on *Pinus contorta, P. jeffreyi,* and *P. ponderosa.*

II and III on at least 10 species of Castilleja, 2 of Orthocarpus, and 1 of Pedicularis.

Distribution:—Throughout the Rocky Mountain and Pacific Coast regions from Canada to Mexico.

Remarks:—The Cronartium stage of this species and the similar one from the preceding species are at present indistinguishable. The data on telial hosts given above are from specimens, some of which may belong to the preceding species.

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[5] Species under No. 3 designated by the asterisk (*) were successfully inoculated by Hedgcock and Hunt with aeciospores of *Peridermium harknessii* on *Pinus contorta* from Wyoming.

Peridermium filamentosum is characterized by little or no conspicuous swelling, and by conspicuous blister-like peridia, in distinction to the preceding gall-forming species which has inconspicuous peridia which are not in the form of blisters. The absence of intergrading forms between the two species is noted by Hedgcock, Bethel, and Hunt.

Hedgcock (56) in 1912 proved that *Peridermium filamentosum* is the aecial stage of Cronartium on Castilleja, and, on grounds of priority, assigned to it the name *Cronartium filamentosum*. Meinecke (95) in 1912 proved that *Peridermium stalactiforme* (now regarded as a synonym of *P. filamentosum*) also is the aecial stage of Cronartium on Castilleja and assigned it to the same species. Weir and Hubert (138) in 1915 verified the work of Hedgcock and Meinecke. Hedgcock, Bethel and Hunt (69) in 1917, found the pycnia of this fungus for the first time.

5. **Cronartium comptoniae** Arth. (5; 9; 20; 21; 22; 26; 27; 36; 39; 83; 91; 98; 112; 118; 120; 122; 124; 141; 142).

Hosts:—

O and I [= **Peridermium comptoniae** (Arth.) Orton & Adams] on the following 2- and 3-needled species of Pinus:

banksiana	maritima*	nigra austriaca*	rigida*
contorta*[6]	montana*	ponderosa	sylvestris*
densiflora	mugho	pungens*	taeda
echinata	nigra*	resinosa*	virginiana
jeffreyi*			

II and III on *Comptonia (asplenifolia) peregrina, Myrica gale,* and *Myrica carolinensis.*[*7]

Distribution:—From New Hampshire south to North Carolina; west to Minnesota and Missouri.

Remarks:—The aecia of this species are characterized by sharp, tooth-like projections on the edges of the broken peridium. To young pines this Peridermium is very harmful, not only in our eastern nurseries, but also in the forest. It has proven especially destructive to western pines introduced into the East.

Clinton (26 and 27) in 1907 established by inoculations the aecial stage belonging to this Cronartium. Weir and Hubert (142) in 1917 described the pycnia of this species. Spaulding (118; 120; 122 and 124) has called attention to the destructive effect of this species on pines.

6. **Cronartium occidentale** Hedgc., Bethel & Hunt (70).

Hosts:—

O and I (**Peridermium occidentale** Hedgc., Bethel & Hunt) on *Pinus edulis* and *P. monophylla.*

II and III on *Ribes aureum, R. odoratum, R. inebrians,* and *Grossularia leptantha,* in nature; by inoculations by Hedgcock, Hunt and Rhoads, on *Ribes americanum,** *R. giraldi,** *R. malvaceum,** *R. nigrum,** and *R. sanguineum,** also on *Grossularia inermis.**

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[6] The telial stage from hosts of the species under No. 5 indicated by the asterisk (*) has been obtained by inoculations on *Comptonia (asplenifolia) peregrina* by Spaulding, Lyman, Gravatt, and Hedgcock.

[7] From inoculations by Weir and Hubert (141).

Distribution:—From Kansas to Colorado and Arizona.

Remarks:—This Cronartium is closely related to *Cronartium ribicola,* but is apparently a distinct species. Circumstantial evidence indicates that it may overwinter on Ribes. The Peridermium shows greater morphological difference from *Peridermium strobi* than the Cronartium stage. It apparently lacks the virulence of the white pine blister rust and is known to attack only the nut or piñon pines which are considered to be of very little commercial value. All evidence thus far obtained seems to indicate that the white or 5-needled pines are immune to the attack of this rust.

Bethel in 1897 first discovered this Cronartium. Hedgcock in 1917 found the first specimen of the Peridermium. Both verified the relation between the aecial and telial stages as established by Hunt in 1917 (70).

7. **Cronartium pyriforme** (Peck) Hedgc. & Long. Syn.:—*Cronartium comandrae* Peck. (11; 21; 22; 23; 24; 30; 36; 39; 42; 53; 69; 72; 73; 76; 77; 86; 91; 98; 102; 128; 136; 142).

Hosts:—

O and I [= **Peridermium pyriforme** Peck. (P. *Betheli* Hedgc. & Long)] on the following 2- and 3-needled species of Pinus:

arizonica	maritima	ponderosa	sylvestris
banksiana	murrayana	pungens	virginiana?
contorta	nigra austriaca	rigida	

II and III on *Comandra pallida,* and *C. umbellata.*

Distribution:—From the northern and northeastern United States, Alberta, and British Columbia, south through the western United States to Mexico.

Remarks:—This species is characterized by pyriform aeciospores. In form it is a true blister rust. It is very destructive to young pines in the Rocky Mountain and Pacific Ocean regions. Hedgcock and Long (73) in 1914 established by inoculations the relation of the Peridermiun to this Cronartium, which had previously been suggested by Arthur and Kern (21) in 1913, and assigned the name *Cronartium pyriforme* on grounds of priority. Boyce (24) in 1916 found the pycnia of this species.

8. **Cronartium ribicola** Fischer. (11; 22; 28; 29; 30; 32; 33; 34; 93; 94; 110; 111; 115; 117; 121; 122; 123; 125; 127; 130; 131; 132).

Hosts:—

O and I (= **Peridermium strobi** Kleb.) on the following 5-needled species of Pinus:

cembra	flexilis	monticola	peuce
excelsa	lambertiana	parviflora	strobus[8]

[8] *Cronartium ribicola* will probably be found able to attack most of the other 5-needled white pines of the world, including *Pinus albicaulis, P. aristata, P. ayacahuite, P. balfouriana, P. koriaensis,* and *P. strobiformis.* The most important varieties included in the foregoing species are *P. coronans, P. formosana, P. mandschurica, P. mastersiana, P. morrisonicola, P. nepalensis, P. pentaphylla, P. pumila,* and *P. scipioniformis.* The 5-needled pitch pines, *P. arizonica* and *P. torreyana* are not expected to prove susceptible. No other rust is known to attack white pines.

II and III on all species of Ribes and Grossularia that have been tested. Eighty-two varieties of cultivated red, black, and white currants, 23 varieties of cultivated gooseberries, and 48 species and hybrids of Ribes from various parts of the world have been proved to be more or less susceptible by Spaulding and Gravatt (127).

Distribution:—Permanently established in Quebec, Ontario, New England, New York, and possibly Minnesota and Wisconsin. Nursery infections in Pennsylvania, Virginia, Ohio, Indiana, Michigan, and South Dakota apparently have been eradicated. Common throughout Europe, and reported from China, Japan and Siberia.

Remarks:—This blister rust has forced the abandonment of the planting of *Pinus strobus* in many parts of Europe, and, since its importation on European nursery stock has proved amply able to destroy native white pines in the United States. State and federal agencies are now cooperating in an effort to control it and prevent its spread to our western forests.

Spaulding (117; 121; 122; 123; 125; and 127) has made an intensive study of this Cronartium in the United States.

The finding of mycelium in the stem tissue in Ribes by Posey, Gravatt and Colley (111) indicates that the fungus may overwinter on this host.

COLEOSPORIUM

Aecial stage, Peridermium on leaves of Pinus: telial stages, on various dicotyledonous plants, especially composites.

9. **Coleosporium campanulae** (Pers.) Lév. (4; 12; 20; 22; 27; 36; 80; 84; 89; 90).

Hosts:—

O and I (= **Peridermium rostrupi** Ed. Fisch.) on *Pinus rigida* and *P. virginiana.*

II and III on species of Campanula and Specularia.

Distribution:—From Connecticut and New Jersey west to Indiana; south to North Carolina. Also in Europe and Asia.

Remarks:—While the relationship between a Peridermium on pine leaves and a Coleosporium on Campanula was first shown by European investigators, Kellerman (78) in 1904 was the first in this country to produce *Coleosporium campanulae* from a Peridermium on *Pinus rigida,* collected in Ohio. Arthur and Kern (20) in 1906 called the aecial stage *Peridermium rostrupi,* after the European form, though previously it had not been considered distinct from our common *Peridermium acicolum.*

Blasdale and Bethel have made collections of this Coleosporium on cultivated plants of Campanula growing on the Exposition grounds at San Francisco, California, where it evidently overwintered. There is also evidence of it overwintering in the eastern United States.

10. **Coleosporium delicatulum** (Arth. & Kern) Hedgc. & Long. (20; 22; 29; 65; 71; 75; 80; 126).

Hosts:—

O and I (= **Peridermium delicatulum** Arth. & Kern) on the following 2- and 3-needled species of Pinus:

contorta	heterophylla	palustris	rigida
echinata	mayriana	ponderosa	serotina
glabra	nigra	resinosa	taeda

II and III on *Euthamia caroliniana, E. graminifolia,* and *E. leptocephala.*

Distribution:—From New Hampshire and Connecticut west to Illinois and Kansas, and south to Florida and Texas.

Remarks:—The Peridermium of this species has very inconspicuous peridia and is very distinct morphologically from other species. Clinton (29) in 1912 predicted the relation of the Peridermium to the Coleosporium. Hedgcock and Long (71) in 1913 made confirmatory cultures, successfully inoculating plants of *Euthamia graminifolia* with aeciospores from *Pinus rigida.* Similar results with the aeciospores from *Pinus echinata, P. heterophylla, P. palustris,* and *P. taeda* have since been obtained by Hedgcock and Hunt. They also have obtained the aecial stage on *Pinus contorta, P. glabra, P. mayriana, P. patustria, P. rigida,* and *P. serotina* with the telia from *Euthamia gramnifolia.* Inoculations with the aeciospores for three successive years on species of Solidago and Aster by Hedgcock and Hunt have given negative results.

11. **Coleosporium elephantopodis** (Schw.) Thüm. (11; 20; 22; 75; 78; 80; 90; 134).

Hosts:—

O and I [= **Peridermium carneum** (Bosc) Seym. & Earle, Am. Auct. *Peridermium intermedium* Arth. & Kern. Am. Auct.] on *Pinus echinata, P. heterophylla, P. mayriana, P. paluslris, P. rigida,* and *P. taeda.*

II and III on at least 7 species of *Elephantopus.*

Distribution:—From New Jersey to Illinois and Missouri south to Florida and Texas. Also in the West Indies and Central America.

Remarks:—Hedgcock and Long (78) in 1914 and 1915 proved that a form of *Peridermium carneum,* as now known, is the aecial stage of this Coleosporium. Hedgcock and Hunt made repeated successful inoculations on *Pinus heterohhylta, P. mayriana,* and *P. taeda* with the telia of this rust. The resulting aecia, both in 1915 and 1916, infected Elephantopus but failed to inoculate Vernonia. They also successfully inoculated Elephantopus with a form of *Pertdermium intermedium* from *Pinus echinata* from Georgia. The aecial stages of *C. elephantopodis* and *C. vernoniae* are closely alike in morphology and have not been described separately. Hedgcock in 1915 and 1916 found the rust overwintering on *Elephantopus caroliniana* in Virginia and other states farther south.

12. **Coleosporium helianthi** (Schw.) Arth. Syn:—*C. viguierae* Diet. & Holw., *C. verbesinae* Diet. & Holw. (11; 63; 67; 80; 90).

Hosts:—

O and I (= **Peridermium helianthi** (Schw.) Hedge. & Hunt) on *Pinus virginiana.*

II and III on at least 11 species of Helianthus, 6 of Verbesina, and 1 of Viguiera.

Distribution:—From New York west to Minnesota; south to Florida and Texas. Also in Mexico, Central America, and the West Indies.

Remarks:—Hedgcock found this Peridermium in 1914, and Hedgcock and Hunt (63) in 1915 and 1916 made successful inoculations with the aeciospores

of *Peridermium helianthi* on 4 species of Helianthus, establishing it as the aecial stage of this Coleosporium. The Coleosporium found on Verbesina and Viguiera has never been connected with the aecial stage by inoculations. It may not belong here and by some authors is considered as a distinct species, especially tropical.

The Peridermium is closely related to that of *Coleosporium inconspicuum*, but inoculations by Hedgcock and Hunt have failed to prove them identical. Repeated inoculations with aeciospores of this Peridermium on *Verbesina virginica* also have given negative results.

13. **Coleosporium inconspicuum** (Long) Hedgc. & Long. (22; 54; 56; 71; 75; 87).
Hosts:—
O and I (= **Peridermium inconspicuum** Long) on *Pinus echinata* and *P. virginiana*.
II and III on at least 4 species and 3 varieties of Coreopsis.
Distribution:—From Maryland to Georgia.
Remarks:—This species is closely related to *Coleosporium helianthi*, but differs slightly in the aecial form. Long (87) found and described *Peridermium inconspicuum* in 1912 and it was proved to be the aecial stage of this species by Hedgcock and Long (71) in 1913. Hedgcock (71) and Hunt have repeatedly inoculated plants of a number of species of Helianthus, Vernonia, and Solidago with aeciospores of this rust, but without infection.

14. **Coleosporium ipomoeae** (Schw.) Burrill. Syn.: *C. guaraniticum* Speg. (11; 61; 67; 80; 89; 90).
Hosts:—
O and I [= **Peridermium ipomoeae** (Schw.) Hedgc. & Hunt] on *Pinus echinata*, *P. palustris*, *P. rigida*, and *P. taeda*.
II and III on at least 1 species of Calonyction, 2 of Convolvulus, 13 of Ipomoea, 4 of Pharbitis, 2 of Quamoclit, and 1 of Jacquemontia.
Distribution:—From Pennsylvania west to Illinois; south to Florida and Texas. The Coleosporium stage is also found in the West Indies, Mexico, Central America and South America.
Remarks:—The Peridermium belonging to this Coleosporium was found by Hedgcock in 1915, and its relationship established by Hedgcock and Hunt (61 and 67) in 1916 to *Coleosporium ipomoeae* on Ipomoea, Pharbitis and Quamoclit. There is abundant evidence that this Coleosporium overwinters in the uredinial stage on perennial species of Convolvulus and Ipomoea.

15. **Coleosporium laciniariae** Arth. (12; 65; 67; 90).
Hosts:—
O and I (= **Peridermium fragile** Hedgc. & Hunt) on *Pinus palustris*, *P. rigida*, and *P. taeda*.
II and III on at least 8 species of Laciniaria
Distribution:—From New Jersey to Florida and Arkansas.
Remarks:—*Peridermium fragile* was first found by Hedgcock frequently associated with *Coleosporium laciniaria* in Florida and New Jersey. It was first collected by him in 1915 at Jacksonville, Florida. He found evidence that it frequently overwinters in the uredinial stage on rosette plants of Laciniaria. Hedgcock and Hunt in 1918 have proved by inoculation the relationship of *Peridermium fragile* to this Coleosporium.

16. **Coleosporium madiae** Cke. (11; 22; 97).

Hosts:—

O and I (= **Peridermium californicum** Arth. & Kern) on *Pinus radiata*.

II and III on 1 species of Anisocarpus, 1 of Madaria, 6 of Madia, and 1 of Zonanthemis.

Distribution:—From Washington south to California, along the Pacific Coast.

Remarks:—*Coleosporium madiae* and *Peridermium californicum* are placed together here on the basis of advance information received from Dr. Meinecke which he kindly allows us to publish in order to make this list as complete as possible. The data from which he draws his conclusions are to be published soon by him.

17. **Coleosporium ribicola** (C. & E.) Arth. (12; 53; 88; 128; 129).

Hosts:—

O and I [= **Peridermium ribicola** (C. & E.) Long] on *Pinus edulis* and *P. pinea*.*

II and III on species of Ribes and Grossularia.

Distribution:—From Montana south to New Mexico, Arizona and Mexico.

Remarks:—Long (88) in 1916 proved by inoculation the connection between the Peridermium on *Pinus edulis* and the Coleosporium on *Ribes inebrians*. In 1916 Hedgcock and Hunt successfully inoculated the needles of *Pinus pinea* with teliospores of the rust from *Ribes inebrians* from Boulder, Colorado. In 1917 Hunt verified Long's work by successful inoculations on *Ribes odoratum* with aecial material sent from Colorado by Hedgcock. Bethel and others have found circumstantial evidence that this rust overwinters in the uredinial stage in Colorado. It extends nearly 400 miles north of the range of *Pinus edulis*.

18. **Coleosporium senecionis** (Schum.) Fries. (11; 27; 40).

Hosts:—

O and I (= **Peridermium oblongisporium** Fuckel) on *Pinus sylvestris* in Europe.

II and III on *Senecio vulgaris*.

Distribution:—In Rhode Island. Common in South America, Europe and Asia.

Remarks:—In North America, *Coleosporium senecionis* has been found on *Senecio vulgaris*, apparently in one locality (Rhode Island), and was probably introduced from Europe. The aecial stage is not known outside of Europe.

This is the species of Coleosporium whose life-history has been longest known; Wolf first experimentally demonstrated it in 1872, followed by Plowright in 1882, as well as by Cornu, Hartig, Rathay, von Thümen, Rostrup, Klebahn, and Fischer. In parts of Europe, *Senecio vulgaris* continues to live throughout the winter. Magnus and others have found the urediniospores throughout the year, so that the intervention of the alternate host in this case is not necessary.

Clinton (27) suggests that this species may be identical with *Coleosporium solidaginis*. Bethel has found a Coleosporium on Senecio in Colorado, which he finds associated with and probably related to *Coleosporium solidaginis*. Hedgcock and Hunt, however, have been unable to infect *Senecio aureum* and *S. obovatum* with the aeciospores of *Coleosporium solidaginis*, by repeated inoculations.

19. **Coleosporium solidaginis** (Schw.) Thum. (11; 20; 22; 25; 27; 36; 48; 57; 58; 60; 64; 75; 80; 89; 90; 91; 92; 98; 109; 126; 133; 134; 136; 137; 143).

Hosts:—

O and I [= **Peridermium acicolum** Underw. & Earle. (? *P. montanum* Arth. & Kern)] on the following 2- and 3-needled species of Pinus:

banksiana	mayriana	ponderosa	serotina*
contorta	montana	pungens	taeda
echinata	nigra	resinosa	thunbergii
heterophylla	nigra austriaca	rigida	

II and III on at least 43 species of Aster, 61 of Solidago, 1 of Callistephus, 1 of Chrysoma, 4 of Chrysopsis, 2 of Doellingeria, 1 of Grindelia, and 1 of Gutierrezia.

Distribution:—From Newfoundland west to British Columbia; south to Florida and central Mexico.

Remarks:—Clinton (25) in 1906 proved that *Peridermium acicolum* is the aecial stage of this Coleosporium. Hedgcock (60) in 1914 by inoculations proved that *Peridermium montanum* is the aecial form of a Coleosporium on Asters which he considered identical with *C. solidaginis*. Weir and Hubert (137) in 1915 corroborated this, and, in addition, successfully inoculated Solidago with this Peridermium.

Arthur and Kern (22) note slight morphological differences between the western and eastern forms of the aecial stage of this Coleosporium. This, in addition to some peculiarities noted in the results of the inoculations by Hedgcock and Hunt indicates possible races or new species and that the problem requires further investigation of both the eastern and western forms.

The Coleosporiums on species of Chrysopsis and Grindelia from Colorado have been found by Bethel to be constantly associated with *Coleosporium solidaginis* on *Aster laevis* and *A. porteri*. He has repeatedly, in the open, successfully inoculated plants of species of Chrysopsis and Grindelia with urediniospores from *Aster laevis*. Control plants, also in the open, remained free from the rust. The work should be repeated under fully controlled conditions.

This rust commonly overwinters on the rosettes of species of Solidago and Aster in many parts of the United States from New Hampshire to Montana, south to Florida and Texas. Clinton (27) in 1908 called attention to the fact that the uredinial stage of this species is found on rosettes of asters and goldenrods in Connecticut, from December to April, before any infection could have occurred from the aecial stage on pines. Ludwig (89) in 1914 comments upon the common occurrence of this species on species of Aster and Solidago in Indiana in the absence of the pine hosts. Bethel in Colorado in 1914 and the following years found it overwintering in the rosettes of *Aster laevis* and *A. porteri*, *Solidago missouriensis* and *S. oreophila* many miles from any possible aecial host. The nearest known locality for the aecia is Estes Park, 50 miles away, where it was collected by Hedgcock and Bethel on *Pinus contorta* in 1917, and now reported for the first time. Mains (92) in 1915 corroborated Clinton's observations and found that viable urediniospores occur on rosettes of Solidago in sori in January and February. Weir and Hubert (143) have made collections of

infected rosettes of Aster and Solidago in March and April in Idaho and Montana. Hedgcock has collected it on Solidago in Florida in a number of localities far from the known southern limit of the aecial stage.

20. **Coleosporium sonchi-arvensis** (Pers.) Lév., Syn.:—*Coleosporium sonchi* Lév. (22; 35; 37; 39; 80).

Hosts:—

O and I (= **Peridermium fischeri** Kleb.) on *Pinus banksiana?* and *P. sylvestris.*

II and III on *Sonchus asper.*

Distribution:—Known from Vermont, Massachusetts, Wisconsin, and Indiana. Probably introduced from Europe.

Remarks:—This species is European and has been found only sporadically in the United States. Davis (35) collected the aecia in 1913 near Sturgeon Bay, Wisconsin, on *Pinus sylvestris* in direct association with the telial stage on *Sonchus asper.* He also found a single needle of *Pinus banksiana* which bore aecia of probably the same species.

The heteroecism of this species was first demonstrated by Ed. Fischer. (Bull. Soc. Bot. France **41**: 169, 1894).

21. **Coleosporium terebinthinaceae** (Schw.) Arth. (11; 62; 67; 80; 89).

Hosts:—

O and I [= **Peridermium terebinthinaceae** (Schw.) Hedgc. & Hunt] on *Pinus echinata, P. rigida, P. taeda,* and *P. virginiana?*

II and III on at least 1 species of Parthenium, 1 of Polymnia, and 12 of Silphium.

Distribution:—From Maryland west to Illinois; south to Georgia and Texas. Also in Mexico.

Remarks)—Hedgcock discovered the aecial form in 1916, and, assisted by Hunt (62 and 67), proved its relationship, successfully inoculating species of Parthenium and Silphium. The Coleosporium on Polymnia has never been proven to be related to *Peridermium terebinthinaceae.*

22. **Coleosporium vernoniae** B. & C. (11; 16; 17; 18; 20; 22; 27; 42; 75; 78; 80; 89; 134).

Hosts:—

O and I [= **Peridermium carneum** (Basc.) Seym. & Earle, Am. Auct. (*Peridermium intermedium* Arth. & Kern) Am. Auct.] on the following 2- and 3-needled species of Pinus.

clausa	heterophylla	palustris	sabiniana*
coulteri*	mayriana*	ponderosa	serotina
echinata	nigra	resinosa	taeda
glabra	nigra austriaca	rigida	

II and III on at least 19 species of Vernonia.

Distribution:—From Massachusetts west to Nebraska; south to Florida and Texas. Also in Mexico.

Remarks:—Arthur (16) in 1910 proved the relation of *Peridermium carneum* to this Coleosporium. Some of the specimens enumerated in collections under the name *Peridermium carneum* here may belong to *Coleosporium elephantopodis, q. v. Coleosporium vernoniae* overwinters in the uredinial

stage on the rosettes of species of Vernonia in the middle and southern Atlantic States. Hedgcock, Long and Hunt find that aeciospores of a Peridermium they assigned to *Peridermium intermedium* from *Pinus echinata* from Arkansas will infect species of Vernonia, and this species, at least in part, now belongs to *Coleosporium vernoniae*.

GALLOWAYA

A short-cycle, autoecious form on leaves of *Pinus virginiana*.

23. **Gallowaya pini** (Galloway) Arth. Syn.: *Coleosporium pini* Galloway. (11; 50; 51; 54).

Hosts:—

O, I, and II lacking.

III on *Pinus virginiana*.

Distribution:—From Maryland south to Tennessee.

Remarks:—This interesting species of rust was found and described by Galloway (50) in 1899 who described its life history in full detail (51). This short-cycle, autoecious form in which only telia are found was later made the basis for a separate genus, Gallowaya, by Arthur (11). Hedgcock, after several years' observations confirms Arthur's suggestion that pycnia are lacking. The telia complete their development on last year's needles in May or June, germinate at once, and the sporidia infect the young needles. The fungus is rare.

MELAMPSORA

Aecial stage, a Caeoma on leaves of Abies, Larix, Pseudotsuga, and Tsuga; telial stages, on various dicotyledonous plants, particularly the Salicaceae.

24. **Melampsora bigelowii** Thüm. Syn.;—*Melampsora paradoxa* Diet. & Holw., *Uredo bigelowii* (Thüm.) Arth. (4; 8; 11; 30; 31; 36; 45; 47; 48; 52; 53; 57; 80; 89; 90; 91; 128; 129; 136; 139; 141; 145).

Hosts:—

O and I (= **Caeoma bigelowii** (Thüm.) Arth.) on *Larix decidua**, *L. laricina*, *L. lyallii*, and *L. occidentalis*.

II and III on nearly all species of Salix.

Distribution:—Nearly throughout continental North America, on willows even a thousand miles from the nearest larches.

Remarks:—Bethel (N. A. Ured., 1617) has found that this rust overwinters in the uredinial stage on the younger stems of willows; also in the catkin buds of *Salix geyeriana*.

Arthur (4) in 1904, and later (8) in 1906, proved that the aecial form of this species is a Caeoma on Larix.

25. **Melampsora medusae** Thüm. Syn.;—*Uredo medusae* (Thüm.) Arth. (3; 4; 7; 11; 12; 31; 36; 46; 48; 52; 57; 80; 89; 90; 91; 128; 133; 141; 148).

Hosts:—

O and I (= **Caeoma medusae** Thüm.) on *Larix decidua,** *L. laricina, L. lyallii,* and *L. occidentalis.*

II and III on nearly all species of Populus.

Distribution:—Nearly throughout the United States and Canada. Also in Mexico, Central America, and South America.

Remarks:—This rust, like the preceding, is found at long distances from the larches. It often causes an early defoliation of the poplars. Arthur (3) in 1903, (4) in 1904, (7) in 1905, and (12) in 1908, proved that a Caeoma on Larix is the aecial stage of this Melampsora. Weir and Hubert (148) in 1917 report confirmatory inoculations of *Melampsora medusae* from *Populus trichocarpa* with telia on *Larix occidentalis* and *L. decidua,* and from *Populus tremuloides* on *Larix occidentalis.*

26. **Melampsora albertensis** Arth. Syn.:—*Uredo albertensis* Arth. (7; 10; 11; 16; 17; 53; 128; 148).

Hosts:—

O and I (= **Caeoma occidentale** Arth.) on *Pseudotsuga macrocarpa* and *P. taxifolia.*

II and III on *Populus acuminata, P. angustifolia, P. balsamifera, P. sargentii, P. tremuloides,* and *P. trichocarpa.*

Distribution:—From Alberta and British Columbia south through the Rocky Mountains to Mexico.

Remarks:—Arthur (10) described this species in 1907 from telial specimens from Alberta. Holway first collected the aecial stage in 1907 from British Columbia, and Arthur assigned it to *Caeoma occidentale.* Bethel in 1908 found the aecial form in abundance on *Pseudotsuga taxifolia* in Colorado, in direct association with the telial stage on Populus. Arthur (16) in 1910 with telial material collected by Bethel in Colorado made inoculations on *Pseudotsuga taxifolia* and *Larix laricina,* obtaining the aecial stage, a Caeoma, in abundance on the former host. He repeated the inoculations in 1911 (17) with the same result, but each time failed to infect Larix. Most collections of *Melampsora* on Populus made elsewhere than in the Rocky Mountains and assigned to this species do not belong here.

Weir and Hubert (148) in 1917, using material from the open forest, find that either *M. medusae* or *M. albertensis* will go on both Larix and Pseudotsuga irrespective of the source or appearance of the telia, and suggest that these two forms are but different host manifestations of the same rust which apparently should be referred to *M. medusae.* However, since, as Weir and Hubert state, these two forms have no sharp differential characters, either in their gross or minute details, pedigreed cultures will be necessary to prove their conclusion, especially in view of Arthur's negative results (16 and 17) with *M. albertensis* on Larix.

27. **Melampsora occidentale** Jackson (82).

Hosts:—

O and I unknown.

II and III on *Populus acuminata, P. angustifolia, P. balsamifera, P. balsamifera candicans,* and *P. trichocarpa.*

Distribution:—From Wyoming and Montana west to California, Oregon, and British Columbia.

Remarks:—Jackson (82) predicts that the aecial form will be found on Larix. He considers it distinct from *Melampsora medusae*, from which he separated it, and from *M. albertensis*, mainly because of its larger urediniospores.

28. **Melampsora arctica** Rostr. Syn.;—*Uredo rostrupiana* Arth. (11; 38; 45; 46; 90; 128; 147).

Hosts:—

O and I [**Caeoma arctica** (Rostr.) Fraser] on *Abies balsamea, A. concolor,* and *A. grandis.*

II and III on species of Salix.

Distribution:—From Greenland west to British Columbia and south through the Rocky Mountains to Guatemala. Also in Europe.

Remarks:—Fraser (45) in 1911 and again (46) in 1912 proved by inoculations with telia from *Salix discolor* on *Abies balsamea* that the aecial stage is a Caeoma on Abies. Bethel first in 1915, and Weir and Hubert (147) in 1917 verified Fraser's work by inoculations. Bethel made successful inoculations with aeciospores from *Abies concolor* on *Salix scouleriana;* and Weir and Hubert (147) with aeciospores from *Abies grandis* on the same species.

29. **Melampsora abietis-canadensis** (Farl.) Ludwig. (14; 31; 36; 38; 41; 45; 46; 80; 90; 115; 116; 119).

Hosts:—

O and I [= **Caeoma abietis-canadensis** Farl. (*Peridermium fructigenum* Arth.)] on *Tsuga canadensis* and *T. heterophylla.*

II and III on *Populus balsamifera, P. balsamifera candicans, P. deltoides, P. grandidentata, P. heterophylla, P. sargentii,* and *P. tremuloides.*

Distribution:—From Nova Scotia west along the northern border of the United States and adjoining Canada to Washington, extending south in the northeastern United States through New England to Pennsylvania.

Remarks:—The stage on leaves of *Tsuga Canadensis* was described by Farlow (41) in 1885 as *Caeoma abietis-canadensis.* The rust on the cones was first collected by Spaulding in Connecticut and described as *Peridermium fructigenum* by Arthur (14) in 1910. Later Spaulding (115) in 1911, correctly judging the rust to be a Caeoma, published it under the name *Caeoma tsugae,* without, however giving a description.

The uredinia and telia of this rust were formerly confused with those of *Melampsora medusae.* Fraser (45) in 1911, and (46) in 1912, successfully inoculating *Tsuga canadensis* with the telia of this *Melampsora* from *Populus grandidentata,* concluded that he had a specialized form of *M. medusae.* Ludwig (90), in describing *Melampsora abietis-canadensis,* places Fraser's material used in the latter's inoculations, under this species.

PUCCINIASTRUM

Aecial stage, a Peridermium on leaves of Picea and Abies; telial stages, on various dicotyledonous plants, particularly the Ericales.

30. **Pucciniastrum pustulatum** (Pers.) Diet. Syn.;—*Uredo pustulata* Peers. *Pucciniastrum epilobii* Otth., *Pucciniastrum abieti-chamaenerii* Kleb (11; 27; 36; 44; 45; 52; 128; 136; 140; 141; 143).

Hosts:—

O and I (= **Peridermium pustulatum** Pers.) on *Abies balsamea, A. concolor, A. grandis,* and *A. lasiocarpa.*

II and III on *Chamaenerion (Epilobium) angustifolium* and species of Epilobium.

Distribution:—From Nova Scotia west to Alaska; south to Delaware, New Mexico, and California. Also in Europe.

Remarks:—In Europe, according to Sydow (Monographia Uredinearum **3**: 443, 1914), Klebahn, Ed. Fischer, Tubeuf, and Bubák have established experimentally the relation of the aecial form on *Abies pectinata* to Pucciniastrum on *Chamaenerion angustifolium,* under the name *P. abieti-chamaenerii.* Sydow places the Pucciniastrum on species of Epilobium under *P. epilobii.* Weir and Hubert (143), not being able to transfer the uredinial stage by inoculation from *Epilobium adenocaulon* to *Chamaenerion angustifolium,* think also that the two forms may be distinct species.

Fraser (45) in 1911 was first in America to establish by inoculations the relation between the aecial stage on *Abies balsamea* and the telial stage on *Chamaenerion angustifolium.* Bethel (in Mss.) in 1914 obtained the Peridermium stage on *Abies lasiocarpa* by inoculations with telia from Chamaenerion, and, in the same year, obtained uredinia on *Epilobium adenocaulon* from aeciospores from *Abies concolor.* Weir and Hubert (141) in 1916 produced uredinia on *Chamaenerion angustifolium* by the inoculations of aeciospores from *Abies lasiocarpa* resulting from an inoculation with the telial stage on the same species of Chamaenerion, thus completing the life cycle of this rust.

Bethel in 1912 found this rust wintering over in rosettes of *Epilobium adenocaulon* in Colorado. He finds that telia are rare on the Epilobiums but abundant on Chamaenerion, and that for its aecial infection this rust is always dependent upon the latter host. It lives over winter on species of Epilobium and is often found at long distances from Abies. Bethel and Hunt collected it in 1917 in Mesa Verde National Park, Colorado, at a distance of 75 miles from Abies.

31. **Pucciniastrum myrtilli** (Schum.) Arth. Syn.; *Aecidium ? myrtilli* Schum., *Pucciniastrum minimum* (Schw.) Arth., *P. vacciniorum* Diet., *Uredo minima* Schw., *Caeoma (Uredo) azaleae* Schw. (11; 20; 26; 27; 28; 30; 36; 38; 40; 42; 45; 46; 47; 52; 116; 128).

Hosts:—

O and I (= **Peridermium peckii** Thüm.) on *Tsuga canadensis* and *T. caroliniana.*

II and III on *Azalea nudiflora* and *A. viscosa,* species of Gaylussacia, *Menziesia pilosa, Rhodora canadensis,* and species of Vaccinium.

Distribution:—From Nova Scotia west to British Columbia; south to Florida and New Mexico.

Remarks:—Clinton (28) in 1910 reported proof with inoculations that *Peridermium peckii* is the aecial stage of this Pucciniastrum and states that this species is probably identical with *P. minimum.* Fraser (45) in 1911 infected leaves and cones of *Tsuga canadensis* with telia from *Rhodora canadense* (*P. minimum*), the resulting aecial material being sent to Dr. Arthur for determination. He replied that the aecial form from *Pucciniastrum minimum* was *Peridermium peckii* and stated that the form

that seemed to be connected to *P. myrtilli* was distinct. The next year Fraser infected leaves of *Tsuga canadensis* with teliosporic material on *Vaccinium canadense* (*P. myrtilli*), producing aecia of the deep reddish-yellow form which had passed as *Peridermium peckii* but which Arthur regarded as distinct. This confirms the life history of *Pucciniastrum myrtilli* as established by Clinton, who sowed aeciospores from *Tsuga canadensis* on *Gaylussacia baccata* and produced the uredinia of *P. myrtlili*. In 1913 Fraser (47) produced aecia on *Tsuga canadensis* with teliosporic material of *P. myrtilli* on *Gaylussacia resinosa*. In a recent communication Dr. Arthur states that Fraser was unquestionably correct and that there is at present no reason for separating *P. minimum* and *P. myrtilli*.

MELAMPSORIDIUM

Aecial stage a Peridermium on leaves of Larix; telial stage on Betulaceae.

32. **Melampsoridium betulae** (Schum.) Arth. Syn.;—*Melampsora betulina* Tul. *Melampsoridium betulinum* (Tul.) Kleb. (11; 20; 27; 36; 80; 145).

Hosts:—

O and I [**Peridermium laricis** (Kleb.) Arth. & Kern. (*Caeoma betulinum* Schlectd.)] on *Larix laricina*.

II and III on *Betula glandulosa*, *B. lutea*, *B. occidentalis* and *B. pumila*.

Distribution:—From Newfoundland west to British Columbia; south to Washington, Idaho, Montana, Wisconsin, and Connecticut. Also throughout Europe and in Japan. The aecial stage apparently is known only from Wisconsin in this country.

Remarks:—Plowright in 1890 (Zeitschr. f. Pflanzenkr., **1**: 130, 1891; Gard. Chron., **8**: 41, 1890), after many unsuccessful trials was the first to discover that the Melampsora on birch was connected with an aecial form on larch. He performed the experiments in both directions and his conclusions were confirmed 8 years later by Klebahn (Zeitschr. f. Pflanzenkr. **9**: 18, 1899). In 1906 Arthur and Kern (20) showed that the aecium was a Peridermium. The aecial stage is known in this country from only a few collections.

The overwintering of this rust has long been known to European writers. Liro found that the urediniospores, either in dry or moist stage, or the mycelium, were capable of wintering over in the tissues of the leaves and buds of seedlings but not in those of older trees. Clinton (27) in 1907 suggested the probable overwintering of this rust, but Weir and Hubert (145) in 1917 were the first in this country to find positive evidence of its overwintering.

MELAMPSORELLA

Aecial stage, a Peridermium on leaves of Abies and Picea, causing the formation of witches' brooms; telial stages on Caryophyllaceae.

33. **Melampsorella elatina** (Alb. & Schw.) Arth. Syn.;—*Aecidium elatinum* Alb. & Schw., *Melampsorella caryophyllacearum* Schröt., *Melampsorella cerastii* Schröt. (1; 11; 17; 20; 36; 40; 42; 52; 53; 57; 58; 59; 89; 101; 104; 106; 128).

Hosts:—

O and I [= **Peridermium elatinum** (Alb. & Schw.) Schw. & Kze.] on *Abies balsamea, A. concolor, A. grandis, A. lasiocarpa, A. magnifica, A. nobilis,* and *A. religiosa.*

II and III on species of Cerastium, and Stellaria (Alsine).

Distribution:—From Labrador west to Alaska; south through Canada to the Northern United States, extending south in the western United States to California and Mexico. Also in Europe and Asia.

Remarks:—The heteroecism of this parasite was established by Fischer in 1901 (Zeitschr. f. Pflanzenkr., **11:** 321). The result was obtained only after long and vain search extending over many years. It has been confirmed by von Tubeuf, Klebahn, and Bubák, and indication of races has been found in Europe.

Arthur (17) in 1911 made the first cultures with American material, proving that the aecial stage on *Abies lasiocarpa* is related to the telial stage on *Cerastium oreophilum.* Weir and Hubert (147) in 1917 made confirmatory cultures, infecting *Stellaria borealis* with aeciospores of *Melampsorella elatina,* both from *Abies grandis* and *A. lasiocarpa.*

The mycelium of both stages, as claimed by the Sydows (Monographia Urediniarum **3:** 436, 1915), is perennial as long as the host survives; for this reason the parasite can maintain itself on either the aecial or telial host quite independently of the alternate one. The aecial stage produces a harmful brooming and dwarfing of the tips and branches.

34. **Melampsorella** sp.? (15; 20; 57; 58; 59; 99; 128; 136; 147).

Hosts:—

O and I [= **Peridermium coloradense** (Diet.) Arth. & Kern (*Peridermium boreale* Arth. & Kern)] on *Picea engelmanni, P. excelsa, P. mariana, P. parryana,* and *P. sitchensis.*

II and III on *Stellaria borealis** and *S. longifolia.*[9]*

Distribution:—From Maine west to Washington; northward into Canada, and south to Central Mexico.

Remarks:—This broom-forming rust is very widespread and harmful in some localities. The mycelium is perennial as in the preceding species. It not only attacks and stunts the twigs and branches of young trees, but also brooms and dwarfs saplings and older trees.

Bethel, who collected the type of *Peridermium boreale* in Colorado in 1897, and Hedgcock, who has collected many specimens, hold that this species is unquestionably the same as *Peridermium coloradense.*

Weir and Hubert (147) in 1917, by inoculations with the aecia of *Peridermium coloradense* from *Picea engelmanni,* successfully infected *Stellaria borealis* and *S. longifolia.* A comparison of the uredinial and telial stages resulting from inoculations with the aeciospores of *Peridermium coloradense* taken from *Picea engelmanni,* and those of *Peridermium elatinum* taken from *Abies grandis* and *A. lasiocarpa,* lead Weir and Hubert (147) to conclude that they belong to one and the same fungus, *Melampso-*

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[9] Under this species of rust the hosts followed by an asterisk (*) have been proved susceptible by Weir and Hubert (141).

rella elatina. They also report the first occurrence of the aecial stage on *Picea excelsa*.

The authors, however, in the absence of confirmatory cross inoculations with telial material prefer to list the two species of Peridermium separately.

CALYPTOSPORA

Aecial stage, Peridermium on leaves of Abies; telial stage on Vaccinium, causing marked swelling and fasciation of the shoots.

35. **Calyptospora columnaris** (Alb. & Schw.) Kühn. Syn.;—*Aecidium columnare* Alb. & Schw., *Calyptospora goeppertiana* Kühn. (11; 13; 20; 30; 40; 43; 44; 45; 47; 48; 136; 147).

Hosts:—

O and I [= **Peridermium columnare** (Alb. & Schw.) Kze. & Schm.] on *Abies balsamea, A. concolor, A. fraseri, A. grandis, A. lasiocarpa, A. magnifica*, and *A. nobilis*.

II lacking.

III on many species of Vaccinium.

Distribution:—From Newfoundland west to British Columbia in Canada; south throughout the northern United States and down into the mountainous regions. Also throughout Europe.

Remarks:—Hartig in 1880 at Munich, Germany, first proved the relation of the aecial stage to the telial, by transferring cultures in both directions. The most extensive cultures were made by Winter in 1885 and 1886 in the garden of the Experiment Station at Halle, Germany (Hedgwigia **26:** 28, 1887). He successfully sowed teliospores on *Abies nobilis, A. magnifica, A. concolor, A. balsamea*, and *A. fraseri*, natives of North America, and also on 8 other species, natives of various other parts of the world.

Arthur (13) in 1909 made the first culture with American material, infecting *Abies fraseri* with telial material on *Vaccinium pennsylvanicum* sent from Nova Scotia by Fraser. Later in the same year Fraser (43) found the aecia on *Abies balsamea* in Nova Scotia, the first collection known in nature from North America. Fraser (45) two years later, in 1911, and again (47) in 1913, infected *Abies balsamea* with telial material from *Vaccinium pennsylvanicum*. It was long believed that pycnia were lacking in this species. They are inconspicuous, but present, and can be found by careful sectioning.

The mycelium is annual in species of Abies, but perennial in the stems of Vaccinium, causing marked swelling and proliferation of the latter.

NECIUM

A short-cycle, autoecious form on cones, leaves, and young stems of Tsuga.

36. **Necium farlowii** Arth. Syn.;—*Melampsora farlowii* (Arth.) Davis. (11; 27; 38; 45; 116).

Hosts:—
O unknown.
I and II lacking.
III on *Tsuga canadensis*.

Distribution:—From the New England states south to North Carolina.

Remarks:—This is a short-cycle form with telia which fill the epidermal cells and resemble a peridium. It was described by Arthur (11) in 1907 from a collection by Seymour at Chebacco Lake, Massachusetts, in June 1883. Clinton (27) states that the occurrence of telia on young stems indicates that the mycelium is sometimes perennial. Frazer (45) in 1911 infected leaves of *Tsuga canadensis* with telial material collected on twigs on this species the preceding year. Davis (38) has pointed out that this rust is a short-cycle form of Melampsora.

UREDINOPSIS

Aecial stage, a Peridermium on leaves of Abies; telial stage on Filicales.

37. **Uredinopsis mirabilis** (Peck) Magn. Syn.;—*Septoria mirabilis* Peck., *Uredinopsis americana* Sydow, *Uredinopsis osmundae* Magn., *Uredinopsis pteridis* Diet. & Holw., *Uredinopsis copelandi* Sydow. *Uredinopsis struthiopteridis* Störm., *Uredinopsis atkinsonii* Magn., *Uredinopsis phegopteridis* Arth. (11; 20; 36; 38; 40; 42; 44; 45; 46; 47; 99; 103; 106; 113; 136; 143).

Hosts:—
O and I [=**Peridermium balsameum** Peck. (*Peridermium pseudo-balsameum* (Diet. & Holw.) Arth. & Kern)] on *Abies amabalis, A. balsamea, A. grandis, A. lasiocarpa,* and *A. nobilis.*
II and III on *Anchistea virginica, Athyrium filix-foemina, A. cyclosorum, Dryopteris thelypteris, Lorinseria areolata, Matteuccia struthiopteris, Onoclea sensibilis, Osmunda cinnamomea, O. claytoniana,* and *O. regalis, Phegopteris dryopteris, Pteridium aquilinum,* and *P. caudatum.*

Distribution:—From Newfoundland west to British Columbia; south to California and Florida. Also in Europe and Japan.

Remarks:—The several species of Uredinopsis on ferns in North America were described in 1907 by Arthur (11) as distinct. Fraser (45 and 46) by inoculations in 1912 and 1913 proved that *Peridermium balsameum* is the aecial stage of *Uredinopsis atkinsonii, U. osmundae, U. struthiopteridis, U. phegopteridis,* and *U. mirabilis.* In 1914 (47) he expressed doubts as to whether *U. mirabilis* should be included with the others. Weir and Hubert (143) in 1916 proved that *Peridermium pseudo-balsameum* on *Abies grandis* in the West is the aecial stage of *Uredinopsis pteridis,* and state that this species is identical with the six species which Fraser studied. They cite from Fraser that Arthur examined all the field collections of *Peridermium balsameum* and the cultures of Fraser and came to the conclusion that there are no morphological differences in the aecial stages produced on *Abies balsamea* by inoculations of the five species of *Uredinopsis.* Weir and Hubert also conclude that *U. copelandi* agrees in morphology with the other six species of this genus, and we have included it here. Further inoculations, however, will be necessary to fully establish the identity of all the species grouped here.

MELAMPSOROPSIS

Aecial stage, Peridermium on leaves and cones of Picea; telial stages on Ericales.

38. **Melampsoropsis abietina** (Alb. & Schw.) Arth. Syn.; *Chrysomyxa ledi* De By. *Melampsoropsis ledi* (Lk.) Arth. (11; 16; 20; 36; 38; 40; 41; 42; 44; 45; 99).

Hosts:—

O and I (= **Peridermium abietinum** Thüm.) on *Picea excelsa, P. mariana,* and *P. rubens.*

II and III on *Ledum glandulosum, L. groenlandicum* and *L. decumbens.*

Distribution:—From Greenland south to Nova Scotia and New Hampshire; west to Wyoming. Also in Euope.

Remarks:—Fraser (44) in 1910, in the field, and again (45) in 1911, under controlled conditions, proved that *Peridermium abietinum* is the aecial stage of this Melampsoropsis by inoculations with the telia on *Picea rubens.* Klebahn in Europe (Zeitschr. f. Pflanzenkrank., **12:** 141, 1902) had already proven this connection by the successful inoculations of *Ledum palustre* with the aeciospores of the Peridermium.

39. **Melampsoropsis cassandrae** (Peck & Clinton) Arth. Syn.;—*Uredo cassandrae* Peck and Clinton, *Chrysomyxa cassandrae* Tranz. (11; 20; 26; 27; 36; 38; 44; 45; 105).

Hosts:—

O and I (= **Peridermium consimile** Arth. & Kern) on *Picea mariana* and *P. rubens.*

II and III on *Chamaedaphne caliculata.*

Distribution:—From Nova Scotia, Ontario, and Wisconsin south to Georgia and Alabama. Also in Europe.

Remarks:—The uredinia overwinter in the old leaves. Clinton (27) in 1908 first proved the relation of *Peridermium consimile* as the aecial stage by obtaining the uredinial stage on *Chamaedaphne calyculata* from inoculations with aeciospores from *Picea mariana* Fraser (44) in 1910, in the field, and again (45) in 1911, under controlled conditions, successfully inoculated *Picea rubens* with telia from *Chamaedaphne calyculata.* This species is often associated with *Peridermium decolorans,* the aecial stage of *Melampsoropsis ledicola.* Rhoads, in 1918, found this species wintering over in the uredinial stage in Maine.

40. **Melampsoropsis ledicola** (Peck) Arth. Syn.;—*Uredo ledicola* Peck. *Chrysomyxa ledicola* Lagerh. (11; 15; 20; 36; 38; 42; 44; 45; 48; 100; 101; 103; 108).

Hosts:—

O and I [= **Peridermium decolorans** Peck (*P. abietinum,* var. *decolorans* Thüm.] on *Picea canadensis, P. engelmanni, P. mariana, P. rubens,* and *P. sitchensis.*

II and III on *Ledum groenlandicum* and *L. decumbens.*

Distribution:—From Greenland to Alaska; south to the northern United States.

Remarks:—This is a common arctic and alpine species. It often discolors the needles of the spruces to such an extent that the foliage of the trees in mass assumes a yellowish hue.

Fraser (44) in 1910, in the field, and again (45) in 1911, under controlled conditions, successfully inoculated the needles of *Picea canadensis* with the telia of this Melampsoropsis on *Ledum groenlandicum*, proving that *Peridermium decolorans* is the aecial stage.

41. **Melampsoropsis pyrolae** (DC.) Arth. Syn.;—*Aecidium* (?) *Pirolae* DC. *Chrysomyxa pirolae* Rostr. (11; 20; 27; 42; 44; 45; 52; 57; 128; 145).

Hosts:—

O and I [= **Peridermium conorum-piceae** (Reess) Arth. & Kern. (*Peridermium engelmanni* Thüm.)] on *Picea canadensis*, P. *engelmanni*, P. *excelsa*, *P. mariana*, *P. parryana*, and *P. rubens*.

II and III on *Moneses uniflora* and species of Pyrola.

Distribution:—From Greenland west to Alaska; south to Maryland, New Mexico, and California. Also throughout Europe.

Remarks:—Spruce cones infested by this fungus turn yellow and produce no seed. The mycelium of the fungus overwinters in the leaves of species of Moneses and Pyrola. Fraser (44) in 1910, in the field, and again (45) in 1911, under both field and controlled conditions, infected cones of *Picea mariana* (also *P. canadensis* in 1911), using telial material from Pyrola, thereby proving that *Peridermium conorum-piceae* is the aecial stage of this Melampsoropsis.

CHRYSOMYXA

A short-cycle, autoecious form on leaves of Picea.

42. **Chrysomyxa weirii** Jackson. (81; 82; 147).

Hosts:—

O unknown.

I and II lacking.

III on *Picea engelmanni*.

Distribution:—From Idaho and Washington north into British Columbia.

Remarks:—This species was first found by Holway in British Columbia in 1911. Weir (147), who collected this rust in Oregon in 1913 and in Idaho in 1915, the former collection being the type, was the first to recognize it as a new species. According to Jackson (81) who described it in 1917 (82), it is a short cycle form referable to the genus Chrysomyxa as it is restricted by Arthur. No inoculations with this rust have been reported.

PERIDERMIUM

(Aecial forms with peridia, whose telial stage is unknown.)

43. **Peridermium minutum** Hedgc. & Hunt. (67).

Hosts:—

O and I on *Pinus glabra and P. taeda*.

II and III an undescribed Coleosporium on *Adelia ligustiona*.

Distribution:—Florida.

Remarks:—This species of Peridermium is morphologically distinct from other known leaf forms, and is known only from Gainesville and Brooksville Florida, where it was discovered by Hedgcock in 1915. Hedgcock, in 1918, found that this species is the aecial form of an undescribed species of Coleosporium on *Adelia* (*Forestiera*) *ligustrina*.

44. **Peridermium gracile** Arth. & Kern. (20; 22.)

Hosts:—

O and I on *Pinus filifolia*.

II and III unknown.

Distribution:—Known only from Mexico.

Remarks:—The type collection was made at Oaxaca in 1894 by C. G. Pringle.

45. **Peridermium guatemalense** Arth. & Kern. (22; 85.)

Hosts:—

O and I on *Pinus filifolia*.

II and III unknown.

Distribution:—Known only from Guatemala.

Remarks:—The type collection was made at Antigua, Department of Sacatepequez, in 1905 by W. A. Kellerman, No. 4626.

46. **Peridermium ornamentale** Arth. Syn.;—*Peridermium holwayi* Syd. (2; 6; 20; 42; 147).

Hosts:—

O and I on *Abies grandis* and *A. lasiocarpa*.

II and III unknown; probably on Vaccinium.

Distribution:—British Columbia, Washington, Idaho, and Montana.

Remarks:—Weir and Hubert (147) qoute a letter from Arthur stating that he is satisfied *Peridermium holwayi* is identical with *P. ornamentale*. They find this rust on *Abies lasiocarpa* in direct contact with Vaccinium bearing the Calyptospora rust and state that, while cultures are necessary in order to determine the relationship definitely, field observations and comparisons with microscopic and macroscopic characters point to the identity of the two forms, *Peridermium ornamentale* and *P. columnare*.

47. **Peridermium ingenuum** Arthur. (20).

Hosts:—

O and I on *Picea canadensis*.

II and III unknown.

Distribution:—Known only from Vermont and Wisconsin.

Remarks:—Arthur (20) remarks as follows concerning this species: "This is the first Peridermium on Picea having subcuticular pycnia to be found in North America. In Europe one such form is known, which was shown by cultures made in 1916 by Ed. Fischer (Mitt. Nat. Ges. Bern 1916: 131. 1917) to belong to *Pucciniastrum sparsum* (Wint.) Ed. Fisch., on Arctostaphylos. The American form doubtless belongs to some species of Pucciniastrum, but probably not to *P. sparsum*, as the spores are considerably smaller than in the European form for that species."

48. **Peridermium ephedrae** Cooke Syn.;—*Peridermium pini minor* Cooke, *Aecidium ephedrae* Dietel. (18; 20; 42; 128).

Hosts:—

O and I on *Ephedra antisyphilitica, E. californica, E. nevadensis, E. torreyana,* and *E. trifurca.*

II and III unknown.

Distribution:—Southwestern United States to Mexico.

Remarks:—This is a common and conspicuous species, attacking both leaves and young stems. The number of the shoots is often augmented and a sort of witches' broom deformity of the attacked branch induced by the perennial mycelium.

CAEOMA

(Aecial forms lacking peridia, whose telial stages are unknown.)

49. **Caeoma conigenum** Pat. (57; 79; 90).

Hosts:—

O unknown.

I on *Pinus chihuahuana.*

II and III unknown.

Distribution:—From New Mexico and Arizona south into Mexico.

Remarks:—Patouillard (Jour. de Botanique **10**: 386, 1896) described and figured this species, stating specifically that there was no pseudoperidium and that it was a Caeoma. House (79), finding cerebroid aecia on a much swollen, deformed cone of *Pinus chihuahuana* from Arizona, assigns the species to *Peridermium cerebrum. P. cerebrum,* however, has not been found on the stems associated with this cone rust, which, however, may be a true Peridermium instead of a Caeoma. Ludwig (90), following Arthur's earlier intimation (6), suggests that this species may be related to *Bubakia mexicana* on Croton, but this is unlikely owing to the recent disposition of the Croton rusts by Arthur (see next species).

50. **Caeoma strobilina** Arth. (6; 89; 90).

Hosts:—

O and I on *Pinus heterophylla, P. palustris,* and *P. taeda.*

II and III unknown.

Distribution:—Florida.

Remarks:—Arthur (6) in 1906 described this species from diseased cones of *Pinus palustris* received from P. H. Rolfs from Palatha, Florida. No peridium was found. This species must not be confused with *Aecidium strobilinum* Reese on cones of *Abies pectinata* in Europe, which is the alternate stage of *Pucciniastrum padi* Diet. (*Thekopsora areolata* (Fr.) Magn.) on *Prunus padus.* Ludwig (90), following Arthur's earlier intimation (6), suggests that this species may be the alternate stage of *Bubakia crotonis* on Croton. However, recent studies of the Croton and allied rusts by Arthur (Bull. Torrey Bot. Club **44**: 501–511, 1917) have thrown the Croton rusts (Bubakia) into the genus Phakopsora. As Dr. Arthur has stated in a recent communication, he is now inclined to think that

the Croton rust and *Caeoma strobilina* have no connection. This later prediction has recently been verified by Hedgcock and Hunt who have successfully inoculated the leaves of species of Quercus with the aeciospores of the fungus obtaining a Uredo form, which is not a Cronartium.

In a fresh collection of cones of *Pinus heterophylla* and *P. palustris* recently sent from Florida by Hedgcock the young cones, which at most were not more than two months old, were infected, producing pycnia which hitherto were unreported, and aecia with no peridia. From this material it was evident that infection must have occurred shortly after the emergence of the new growth from the terminal bud.

A number of second year cones of *Pinus heterophylla* and *P. palustris* from Florida, now in the collections of the Office of Investigations in Forest Pathology, show pseudo-peridia. Hence it is probable that both a Caeoma and a Peridermium may cause a rust of pine cones in Florida, and possibly also in the Southwest.

51. **Caeoma dubium** Ludwig (90).

Hosts:—

O and I on *Tsuga heterophylla*.

II and III unknown.

Distribution:—From the northwestern United States north into southwestern Canada.

Remarks:—This species is distinguished by its subepidermal pycnia from *Melampsora abietis-canadensis* and *Uredo holwayi* on the same host, both of which have subcuticular pycnia. The range of this Caeoma apparently coincides with that of *Melampsora occidentale* to which species it may belong.

52. **Uredo holwayi** Arth. (6; 10; 90; 136).

Hosts:—

O on *Tsuga heterophylla* and *T. mertensiana*.

I unknown.

II on *Tsuga heterophylla* and *T. mertensiana*.

III unknown.

Distribution:—From the northwestern United States north into British Columbia.

Remarks:—This is a unique rust, for which no genus seems rightly constituted. According to Arthur (6) it is physiologically an aecium, and possesses a peridium, but cannot be called an aecium because the spores are born singly on pedicels instead of being catenulate. In gross appearance it resembles an overmature *Peridermium peckii*, which has lost its protruding peridial cells, according to Arthur. He concludes that this is a heteroecious form and assumes, in accordance with the general relationship pointed out by Tranzschel, that the telia will resemble those of *Melampsora abietis-canadensis*, and that the new genus will be closely related to Pucciniastrum. This rust, however, is distinguished from *Melampsora abietis-canadensis* on Tsuga by having echinulate spore-walls and by having the sorus surrounded by a pseudoperidium of paraphyses.

A LIST OF THE UNATTACHED RUSTS WHOSE AECIA ARE LIKELY TO BE FOUND ON CONIFERS

Coleosporium: The following species of Coleosporium are known from the United States: *Coleosporium apocynaceum* Cooke[10] on Amsonia, southern United States; *C. arnicale* Arth. on Arnica, northwestern United States; *C. bletiae* Diet. on Phagus, collected once in California, but probably never became established; *C. occidentale* Arth. on *Senecio*[11] *hydrophiloides*, Washington; and *C. viburni* Arth. on Viburnum, Iowa and Wisconsin to Mexico and central America. The following additional Coleosporiums are known from Mexico, Cuba and Central America: *C. Begoniae* Arth. on Begonia; *C. anceps* Diet. & Holw. on Verbesina; *C. dahliae* Arth. on Dahlia; *C. eupatorii* Arth. on Eupatorium; *C. plumierae* Pat. on Plumiera; *C. steviae* Arth. on Stevia; *C. paraphysatum* Diet. & Holw. on Liabum; *C. mentzeliae* (Diet. & Holw.) Arth. on Mentzelia.

Melampsoropsis: *Melampsoropsis arctostaphyli* (Diet.) Arth. on *Arctostaphylos uva-ursi*, Wisconsin, Colorado, Utah, and Montana; *M. piperiana* Arth. on *Rhododendron californicum*, northwestern United States; *M. chiogenis* (Diet.) Arth. on *Chiogenes hispidula*, Wisconsin to Newfoundland; *M. empetri* (Pers.) Arth. on *Empetrum nigrum*, eastern United States and Canada.

Pucciniastrum: *Pucciniastrum agrimoniae* (Schw.) Tranz. on Agrimonia, Atlantic Coast west to the Rocky Mountains and south into Mexico; *P. arcticum* (Lagerh.) Tranz. on Rubus, from Alaska to Nova Scotia and south to the northern border of the United States; *P. galii* Ed. Fisch., on *Galium aparine*, Colorado and Oregon; *P. goodyerae* (Tranz.) Arth. on Goodyera (Peramium), Colorado to the Pacific Coast; *P. hydrangeae* (B. & C.) Arth. on Hydrangea, eastern and central United States; *P. potentillae* Kom. on Potentilla, Minnesota to northeastern United States and Canada; *P. pyrolae* (Pers.) Diet. on Pyrola and Chimaphila, transcontinental; *P. sparsum* (Wint.) Ed. Fisch. on Arbutus and Arctostaphylos, along the Pacific Coast.

Melampsoridium: *Melampsoridium alni* (Thüm.) Kleb. on Alnus in Guatemala.

The following closely related rusts are known to have no connection with the conifers: *Cionothrix* (*Cronartium*) *praelonga* (Wint.) Arth., an autoecious rust on Eupatorium in Central America; *Uredo* (*Caeoma*)

[10] Hedgcock in March, 1918, found a new species of Peridermium on Pinus heterophylla, P. palustris and P. taeda, associated directly with this Coleosporium, and successful inoculations by Hunt, on Amsonia has proved the connection between the two forms.

[11] The Senecio rusts of Colorado may be related to *Coleosporium solidaginis*.

confluens Pers., I on Ribes in Colorado and Utah, II and III on Salix, not yet reported from North America; *Melampsora (Uredo) alpina* Juel, I on Saxifrage, II and III on Salix, Colorado and Alaska; *Melampsora (Uredo) lini* Desm. on Linum, a cosmopolitan species occurring in southern Canada, northern and western United States as far south as New Mexico; and three or four species of Melampsora on Euphorbia.

HOST INDEX TO NORTH AMERICAN SPECIES OF PERIDERMIUM AND RELATED FORMS

I. INDEX TO PYCNIAL AND AECIAL HOSTS

Numbers in parentheses refer to the serial numbers given the rusts in the body of the paper. Letters preceding the numbers indicate the type of attack on the host, as follows: G = stem rust causing pronounced galls; S = stem rust not causing pronounced galls; WB = leaf and stem rust causing the formation of witches' brooms; C = cone rust; and L = leaf rust. The three first named classes comprise the most dangerous rusts. An asterisk (*) following the name of a rust signifies that the occurrence of this rust on the host indicated is not known in nature, but only as the result of artificial inoculation.

Species of Pinus

arizonica
- G (3) Peridermium harknessii
- S (7) Peridermium pyriforme

attenuata
- G (3) Peridermium harknessii

banksiana
- G (1) Peridermium cerebrum
- S (5) Peridermium comptoniae
- S (7) Peridermium pyriforme
- L (19) Peridermium acicolum
- L (20) Peridermium fischeri ?

cembra
- S (8) Peridermium strobi

chihuahuana
- C (49) Caeoma conigenum

clausa
- G (1) Peridermium cerebrum*
- L (22) Peridermium carneum

contorta
- G (1) Peridermium cerebrum*
- G (2) Peridermium fusiforme*
- G (3) Peridermium harknessii
- S (4) Peridermium filamentosum
- S (5) Peridermium comptoniae
- S (7) Peridermium pyriforme

coulteri
- G (1) Peridermium cerebrum*
- G (2) Peridermium fusiforme*
- G (3) Peridermium harknessii
- L (22) Peridermium carneum*

densiflora
- G (1) Peridermium cerebrum*
- S (5) Peridermium comptoniae

echinata
- G (1) Peridermium cerebrum
- S (5) Peridermium comptoniae
- L (10) Peridermium delicatulum
- L (11) Peridermium carneum
- L (13) Peridermium inconspicuum
- L (14) Peridermium ipomoeae
- L (19) Peridermium acicolum
- L (21) Peridermium terebinthinaceae
- L (22) Peridermium carneum

edulis
G (1) Peridermium cerebrum*
S (6) Peridermium occidentale
L (17) Peridermium ribicola
excelsa
S (8) Peridermium strobi
filifolia
L (44) Peridermium gracile
L (45) Peridermium guatemalense
flexilis
S (8) Peridermium strobi
gerardiana
G (1) Peridermium cerebrum*
glabra
G (1) Peridermium cerebrum
L (10) Peridermium delicatulum*
L (22) Peridermium carneum
L (43) Peridermium minutum
halepensis
G (2) Peridermium fusiforme*
G (3) Peridermium harknesii*
heterophylla
G (1) Peridermium cerebrum
G (2) Peridermium fusiforme
G (3) Peridermium harknessii*
C (50) Caeoma strobilina
L (10) Peridermium delicatulum
L (11) Peridermium carneum
L (19) Peridermium acicolum
L (22) Peridermium carneum
jeffreyi
G (1) Peridermium cerebrum
G (3) Peridermium harknessii?
S (4) Peridermium filamentosum
S (5) Peridermium comptoniae
lambertiana
S (8) Peridermium strobi
maritima
S (5) Peridermium comptoniae
S (7) Peridermium pyriforme
mayriana
G (1) Peridermium cerebrum*
G (2) Peridermium fusiforme*
G (3) Peridermium harknessii*
L (10) Peridermium delicatulum
L (11) Peridermium carneum*
L (19) Peridermium acicolum
L (22) Peridermium carneum*
monophylla
S (6) Peridermium occidentale
montana
G (2) Peridermium fusiforme*
S (5) Peridermium comptoniae
L (19) Peridermium acicolum
monticola
S (8) Peridermium strobi
mugho
S (5) Peridermium comptoniae
muricata
G (1) Peridermium cerebrum?
G (2) Peridermium fusiforme*
G (3) Peridermium harknessii*
nigra
G (1) Peridermium cerebrum
S (5) Peridermium comptoniae
L (10) Peridermium delicatulum
L (19) Peridermium acicolum
L (22) Peridermium carneum
nigra austriaca
S (5) Peridermium comptoniae
S (7) Peridermium pyriforme
L (19) Peridermium acicolum
L (22) Peridermium carneum
oöcarpa
G (1) Peridermium cerebrum
palustris
G (1) Peridermium cerebrum
G (1) Peridermium fusiforme
C (50) Caeoma strobilina
L (10) Peridermium delicatulum
L (11) Peridermium carneum
L (14) Peridermium ipomoeae
L (15) Peridermium fragile
L (19) Peridermium acicolum?
L (22) Peridermium carneum
parviflora
S (8) Peridermium strobi
patula
G (1) Peridermium cerebrum
peuce
S (8) Peridermium strobi
pinea
G (2) Peridermium fusiforme*
G (3) Peridermium harknessii*
L (17) Peridermium ribicola*
ponderosa
G (1) Peridermium cerebrum*
G (2) Peridermium fusiforme*
G (3) Peridermium harknessii
S (4) Peridermium filamentosum

S (5) Peridermium comptoniae
S (7) Peridermium pyriforme
L (10) Peridermium delicatulum
L (19) Peridermium acicolum
L (22) Peridermium carneum

pungens
G (1) Peridermium cerebrum?
S (5) Peridermium comptoniae
S (7) Peridermium pyriforme
L (19) Peridermium acicolum

radiata
G (1) Peridermium cerebrum
G (2) Peridermium fusiforme*
G (3) Peridermium harknessii
L (16) Peridermium californicum

resinosa
G (1) Peridermium cerebrum
S (5) Peridermium comptoniae
L (10) Peridermium delicatulum
L (19) Peridermium acicolum
L (22) Peridermium carneum

rigida
G (1) Peridermium cerebrum
G (2) Peridermium fusiforme
S (5) Peridermium comptoniae
S (7) Peridermium pyriforme
L (9) Peridermium rostrupi
L (10) Peridermium delicatulum
L (11) Peridermium carneum
L (14) Peridermium ipomoeae
L (15) Peridermium fragile
L (19) Peridermium acicolum
L (21) Peridermium terebinthinaceae
L (22) Peridermium carneum

sabiniana
G (1) Peridermium cerebrum*
G (2) Peridermium fusiforme*
G (3) Peridermium harknessii
L (22) Peridermium carneum*

serotina
G (1) Peridermium cerebrum
G (2) Peridermium fusiforme
L (10) Peridermium delicatulum
L (19) Peridermium acicolum*
L (22) Peridermium carneum

strobus
S (8) Peridermium strobi

sylvestris
S (5) Peridermium comptoniae
S (7) Peridermium pyriforme
L (20) Peridermium fischeri
L (22) Peridermium carneum
L (18) Peridermium oblongisporium

taeda
G (1) Peridermium cerebrum
G (2) Peridermium fusiforme
S (5) Peridermium comptoniae
C (50) Caeoma strobilina
L (10) Peridermium delicatulum
L (11) Peridermium carneum
L (14) Peridermium ipomoeae
L (15) Peridermium fragile
L (19) Peridermium acicolum
L (21) Peridermium terebinthinaceae
L (22) Peridermium carneum
L (43) Peridermium minutum

thunbergii
L (19) Peridermium acicolum

virginiana
G (1) Peridermium crebrum
G (3) Peridermium harknessii*
S (5) Peridermium comptoniae
S (7) Peridermium pyriforme?
L (9) Peridermium rostrupi?
L (12) Peridermium helianthi
L (13) Peridermium inconspicuum
L (21) Peridermium terebinthinaceae?
(See also index to telial hosts).

Species of Larix

decidua
L (24) Caeoma bigelowii
L (25) Caeoma medusae

laricina
L (24) Caeoma bigelowii
L (25) Caeoma medusae
L (32) Peridermium laricis

lyallii
L (24) Caeoma bigelowii
L (25) Caeoma medusae

occidentalis
L (24) Caeoma bigelowii
L (25) Caeoma medusae

Species of Picea

canadensis
C (41) Peridermium conorum-piceae
L (40) Peridermium decoloraus
L (47) Peridermium ingenuum
engelmanni
C (41) Peridermium conorum-piceae
WB (34) Peridermium coloradense
L (40) Peridermium
(See also index to telial hosts)
excelsa
C (41) Peridermium conorum-piceae
WB (34) Peridermium coloradense
L (38) Peridermium abietinum
mariana
C (41) Peridermium conorum-piceae
WB (34) Peridermium coloradense
L (38) Peridermium abietinum
L (39) Peridermium consimile
L (40) Peridermium decolorans
parryana
C (41) Peridermium conorum-piecae
WB (34) Peridermium coloradense
rubens
C (41) Peridermium conorum-piceae
L (38) Peridermium abietinum
L (39) Peridermium consimile
L (40) Peridermium decolorans
sitchensis
WB (34) Peridermium coloradense
L (40) Peridermium decolorans

Species of Tsuga

canadensis
S, C, L (29) Caeoma abietis-canadensis
C, L (31) Peridermium peckii caroliniana
L (31) Peridermium peckii
heterophylla
L (51) Caeoma dubium
L (52) Uredo holwayi
mertensiana
L (52) Uredo holwayi
(See also index to telial hosts)

Species of Pseudotsuga

macrocarpa
L (26) Caeoma albertensis
taxifolia
L (26) Caeoma albertensis

Species of Abies

amabalis
L (37) Peridermium balsameum
balsamea
WB (33) Peridermium elatinum
L (28) Caeoma arctica
L (37) Peridermium balsameum
L (35) Peridermium columnare
concolor
WB (33) Peridermium elatinum
L (28) Caeoma arctica
L (35) Peridermium columnare
L (30) Peridermium pustulatum
fraseri
WB (33) Peridermium elatinum
L (35) Peridermium columnare
grandis
WB (33) Peridermium elatinum
L (28) Caeoma arctica
L (37) Peridermium balsameum
L (30) Peridermium pustulatum
L (35) Peridermium columnare
L (46) Peridermium ornamentale
lasiocarpa
WB (33) Peridermium elatinum
L (30) Peridermium pustulatum
L (35) Peridermium columnare
L (37) Peridermium balsameum
L (46) Peridermium ornamentale
magnifica
WB (33) Peridermium elatinum
L (35) Peridermium columnare
nobilis
WB (33) Peridermium elatinum
L (35) Peridermium columnare
L (37) Peridermium balsameum
religiosa
WB (33) Peridermium elatinum

Species of Ephedra

antisyphilitica
WB (48) Peridermium ephedrae californica
WB (48) Peridermium ephedrae nevadensis
WB (48) Peridermium ephedrae torreyana
WB (48) Peridermium ephedrae trifurca
WB (48) Peridermium ephedrae

II. INDEX TO UREDINIAL AND TELIAL HOSTS

In the case of the dicotyledonous hosts it is practicable to give only the genera. In the case of the fern rusts it is not practicable to given even these. Species of rusts not numbered represent the unattached forms whose aecial hosts are unknown, but are likely to occur on conifers.

Adelia
(43) Coleosporium sp.
Agrimonia
Pucciniastrum agrimoniae
Alnus
Melampsoridium alni
Amsonia
Coleosporium apocynaceum
Anisocarpus
(16) Coleosporium madiae
Arbutus
Pucciniastrum sparsum
Arctostaphylos
Melampsoropsis arcotostaphyli
Pucciniastrum sparsum
Arnica
Coleosporium arnicale
Aster
(19) Coleosporium solidaginis
Azalea
(31) Pucciniastrum myrtilli
Begonia
Coleosporium begoniae
Betula
(32) Melampsoridium betulae
Callistephus
(19) Coleosporium solidaginis
Calonyction
(14) Coleosporium ipomoeae
Campanula
(9) Coleosporium campanulae
Castanopsis
(1) Cronartium cerebrum*
Castilleja
(3) Cronartium coleosporioides
(4) Cronartium filamentosum
Cerastium
(33) Melampsorella elatina
Chamadedphne
(39) Melampsoropsis cassandrae
Chamaenerion
(30) Pucciniastrum pustulatum
Chimaphila
Pucciniastrum pyrolae
Chiogenes
Melampsoropsis chiogenis
Chrysoma
(19) Coleosporium solidaginis
Chrysopsis
(19) Coleosporium solidaginis?
Comandra
(7) Cronartium pyriforme
Comptonia
(5) Cronartium comptoniae
Convolvulus
(14) Coleosporium ipomoeae
Coreopsis
(13) Coleosporium inconspicuum
Dahlia
Coleosporium dahliae
Doellingeria
(19) Coleosporium solidaginis
Elephantopus
(11) Coleosporium elephantopodis
Empetrum
Melampsoropsis empetri
Epilobium
(30) Pucciniastrum pustulatum
Eupatorium
Coleosporium eupatorii
Euthamia
(10) Coleosporium delicatulum

Filices
(37) Uredinopsis mirabilis Hyalopsora. (These may be autoecious.)
Galium
Pucciniastrum galii
Gaylussacia
(31) Pucciniastrum myrtilli
Goodyera
Pucciniastrum goodyerae
Grindelia
(19) Coleosporium solidaginis?
Grossularia
(17) Coleosporium ribicola
(6) Cronartium occidentale
(8) Cronartium ribicola
Gutierrezia
(19) Coleosporium solidaginis
Helianthus
(12) Coleosporium helianthi
Hydrangea
Pucciniastrum hydrangeae
Ipomoea
(14) Coleosporium ipomoeae
Jacquemontia
(14) Coleosporium ipomoeae
Laciniaria
(15) Coleosporium laciniariae
Ledum
(38) Melampsoropsis abietina
(40) Melampsoropsis ledicola
Liabum
Coleosporium paraphysatum
Madia
(16) Coleosporium madiae
Madaria
(16) Coleosporium madiae
Mentzelia
Coleosporium mentzeliae
Menziesia
(31) Pucciniastrum myrtilli
Moneses
(41) Melampsoropsis pyrolae
Myrica
(5) Cronartium comptoniae
Orthocarpus
(3) Cronartium coleosporioides
(4) Cronartium filamentosum
Parthenium
(21) Coleosporium terebinthinaceae
Pedicularis
(3) Cronartium coleosporioides
(4) Cronartium filamentosum
Phagus
Coleosporium bletiae
Pharbitis
(14) Coleosporium ipomoeae
Picea engelmanni
(42) Chrysomyxa weirii
Pinus virginiana
(25) Gallowaya pini
Plumiera
Coleosporium plumieriae
Polymnia
(21) Coleosporium terebinthinaceae
Populus
(29) Melampsora abietis-canadensis
Populus
(26) Melampsora albertensis
(25) Melampsora medusae
(27) Melampsora occidentale
Pyrola
(41) Melampsoropsis pyrolae Pucciniastrum pyrolae
Quamoclit
(14) Coleosporium ipomoeae
Quercus
(1) Cronartium cerebrum
(2) Cronartium fusiforme
Rhododendron
Melampsoropsis piperiana
Rhodora
(31) Pucciniastrum myrtilli
Ribes
(17) Coleosporium ribicola
(6) Cronartium occidentale
(8) Cronartium ribicola
Rubus
Pucciniastrum arcticum
Salix
(28) Melampsora arctica
(24) Melampsora bigelowii
Senecio
Coleosporium occidentale
(18) Coleosporium senecionis
(19) Coleosporium solidaginis?
Silphium
(21) Coleosporium terebinthinaceae
Solidago
(19) Coleosporium solidaginis

Sonchus
(20) Coleosporium sonchi-arvensis
Specularia
(9) Coleosporium campanulae
Stellaria
(33) Melampsorella elatina
(34) Melampsorella sp.? (Peridermium coloradense)*
Stevia
Coleosporium steviae
Tsuga canadensis
(36) Necium farlowii
Tsuga heterophylla
(52) Uredo holwayi
Tsuga mertensiana
(52) Uredo holwayi
Vaccinium
(35) Calyptospora columnaris
(31) Pucciniastrum myrtilli
Verbesina
Coleosporium anceps
(12) Coleosporium helianthi
Vernonia
(22) Coleosporium vernoniae
Viguiera
(12) Coleosporium helianthi
Zonanthemis
(16) Coleosporium madiae

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THE PRODUCTION OF AN ANTHRACNOSE-RESISTANT WHITE MARROW BEAN[1]

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During the season of 1915 there was a severe epiphytotic of the anthracnose disease caused by *Colletotrichum lindemuthianum* (Sacc. & Magn.) Bri. & Cav. throughout the bean section of New York State. The writer at that time had the opportunity of visiting a great number of farms where the commercial dry shell beans (*Phaseolus vulgaris* L.) were grown. No variety was observed free from this disease except a certain strain of the Red Kidney. This strain has been reported previously by Barrus[2] as possessing marked resistance to the anthracnose, and is designated by him as the Well's Red Kidney. In addition to being resistant to this disease the strain also is a desirable commercial type of bean. Among the other varieties no such resistance was known and the anthracnose during the season was causing serious losses to the crop.

Although pod selection has been recommended for the control of the anthracnose disease the growers have been very reluctant to practice it. The eagerness, however, with which they grew the Well's Red Kidney, when it became available, made it seem desirable to obtain anthracnose resistant strains of other varieties. For this reason the present work was undertaken.

In considering the production of an anthracnose-resistant bean it was thought best to focus the work on a single variety. Since the writer was located in Wyoming County, New York, which is the center of the White Marrow district, this variety was chosen. The plan was to cross the Well's Red Kidney with the White Marrow bean. Although the main problem was to produce a bean resistant to this disease records were taken of the genetical behavior of the character of anthracnose resistance. The records, though somewhat incomplete, nevertheless, demonstrate the possibilities of improving our present commercial varieties of beans.

The method most frequently used in developing a disease resistant strain of a plant has been selection. Hybridization in a few cases has

[1] The writer wishes to acknowledge his indebtedness to Professor R. A. Emerson for his helpful suggestions in the breeding work.

[2] Barrus, M. F. An anthracnose-resistant red kidney bean. Phytopath. **5**: 303–311. 1915.

been resorted to, but very few data have been accumulated as to the genetical behavior of the character under consideration. Biffen[3] in working with wheat believed that the character of resistance to the yellow rust followed the simple 3 :1 Mendelian ratio. Susceptibility was found to be dominant. Nilsson-Ehle[4] states, however, that this character is more complex, and considers it to be governed by multiple factors. Orton[5] in crossing a wilt-resistant variety of the cowpea with a susceptible variety was of the opinion that the character of resistance behaved in a true Mendelian fashion. No data were taken concerning the ratios, however. He found the same was also true in crossing a wilt resistant citron with a variety of watermelon. Stuckey[6] in 1916 found that resistance to the blossom-end rot in tomatoes is dominant over susceptibility, but he observed no segregation in the F_2 generation. Recently Tisdale[7] studied the results of hybridizing wilt resistant and susceptible strains of flax. Resistance, he states, is inherited and governed by multiple factors.

In considering such a cross as the one between varieties as widely different as the Red Kidney and White Marrow other characters besides disease resistance and susceptibility must be taken into account. The Marrow bean plant has a vining or indeterminate habit of growth similar to that of the Pea bean. The Red Kidney is a typical bush bean. The two varieties also differ in color and shape of seed. The Marrow seed is the largest of the white beans and is plump. The Red Kidney seed is reniform, colored and more or less flat. Some of these characters, doubtless, are governed by several factors, and a half dozen or more factors might be involved in the breeding experiment. For this reason a large number of plants were desirable to obtain the right combination of characters in a single individual.

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[7] Tisdale, W. H. Flax wilt: A study of the nature and inheritance of wilt resistance. Jour. Agr. Research. **11**: 373–605. 1917.

MATERIAL AND METHODS

During the early part of the winter of 1916–1917, seed of the Well's Red Kidney was obtained and planted in the greenhouse together with a select strain of White Marrow seed. It was unfortunate that neither variety of beans was a pure line. They were, however, superior to the common commercial seed. These plants came into blossom during the month of February, and a number of crosses were made. In the majority of cases the White Marrow was used as the female parent, but reciprocal crosses also were made. The flowers were emasculated approximately a day before opening and just prior to the bursting of the anthers. Fresh pollen from the male parent was placed on the pistil at this time.[8] The bean flower is small and the manner in which the stamens are coiled about the pistil makes it exceedingly difficult to emasculate. Nevertheless a number of the crosses were successful. In all, eighty-three flowers were cross pollinated and there were produced twenty-four pods and sixty-six seeds. Thus, no less thon one-third of the crosses set pods, but later a few of these were found to be selfed. Of these twenty-four pods, sixteen were formed on the White Marrow and eight on the Red Kidney. Since xenia does not occur in beans the seeds were identical with that of the female parent

OBSERVATIONS ON THE F_1 HYBRIDS

The spring of 1916 was cold and rainy and the seeds obtained in the greenhouse could not be placed in the ground until late They were planted June 14 at Ithaca in the garden of the Department of Plant Breeding where they could be given special care. These plants were not subjected to the anthracnose because of the possibility of susceptibility being a dominant character. In such a case there would be danger of the destruction of the entire lot. The remainder of the season was dry, however, so no care was needed to guard against natural infection.

The hybrid plants were grown under heavy cloth screens to prevent cross pollination by insects. The bumble bee is considered to be the main offender and possibly the only one on this case. The screens were not placed over the plants until just prior to flowering time and were removed immediately after the plants ceased blossoming. The plants grown under these conditions were very unproductive. They bore rela-

[8] The pollen can be found shortly after the opening of the flower as a gray mass adhering to the inner parts of the flower where it clings after the rupture of anthers The pistil of the female parent should be examined with a hand lens to determine whether it bears any pollen of its own flower. This frequently will avoid cases of selfing.

tively few pods and the number of seeds obtained were not half that to be expected under normal conditions. Some of the plants produced no pods. This was due, no doubt, to the intense heat under the screens which caused the blossoms to drop.

The hybrid plants displayed a vining character as early as the White Marrow, but showed the pink coloration in the flower, similar to the Red Kidney. The pods exhibited strong dashes of red which is characteristic of neither parent. The characters of the F_1 hybrid, though interesting, are not important as segregation will result in a redistribution in the F_2 generation. As stated above comparatively ew seeds were produced by these plants. Five hundred and fifteen were obtained from twenty-one plants averaging 24.52 seeds to a plant. These seeds were plump and a little longer than the Marrow type. In the main they were mottled with brownish purple dashes over a cream-colored body. The seeds from two plants, however, were self colored, the color being an olive brown. According to Emerson[9] the mottling character in the bean is governed by a factor which enters into the cross from the white parent. In this case the factor evidently was lacking in the white bean

F_2 GENERATION

At various times throughout the early winter of 1916–1917 these seed were planted in the greenhouses. The reason for planting them at different times was one of convenience only. As segregation of the character of disease resistance was expected in this generation it was seen that inoculation of small numbers could be handled much more readily and carefully. The seed were planted in 5 and 6 inch pots, the latter preferred, and in one case they were planted in flats. The latter method was unsatisfactory as a large number failed to germinate, and as after inoculation the resistant plants had to be removed to pots for maturing. Furthermore there was a great variation in time of germination due possibly to some of the beans being harvested green. Thus where the seeds were planted in a flat several inoculations were necessary in order that each plant after it came above ground should be treated with the spores of the anthracnose fungus. After inoculation the plants were subjected to moist conditions in a large chamber with glass sides for several days. As the chamber held only fifty 6-inch pots a great many series of inoculations were made. Each plant was treated twice to make certain that infection would take place if possible.

[9] Emerson, R. A. Factors for mottling in beans. Amer. Breeders Assoc. **5**: 368–376. 1909.

The spores used for the inoculations were from the two strains of the pathogene, and were furnished through the courtesy of Dr. M. F. Barrus. Barrus[10] has previously shown that there are at least two distinct physiological strains of *Colletotrichum lindemuthianum*. Many varieties of beans are resistant to one strain but not to both. The Well's Red Kidney, however, is immune to strain A[11] and highly resistant to strain F. The fungi were grown separately and the conidia were mixed in a water suspension just before they were sprayed over the plants. In all cases the check plants of the White Marrow became severely infected.

TABLE 1

PEDIGREE NUMBER	NUMBER OF SEEDS	NUMBER WHICH FAILED TO GERMINATE	NUMBER OF INFECTIONS
Oa	29	0	10
Ob	14	1	4
Ob 1	20	2	9
Od	22	6	2
Od 1	21	6	4
Od 2	31	5	3
Oe	12	1	2
Oe 1	23	3	3
Ib	15	0	5
Ic	19	0	4
Ic 1	39	2	4
Ic 2	38	1	9
Ic 3	59	0	12
Ic 4	43	0	9
Ic 5	13	2	5
Ic 6	10	4	2
If	12	1	3
If 1	12	1	1
Ij	26	2	2
Ik	41	3	14
Misc	16	2	4
	515	42	111

Often the resistant plants showed small lesions of the anthracnose, but seldom was it difficult to determine to which class a plant belonged. It was thought at first that among the diseased individuals there might be varying grades of susceptibility. When it was considered, however, that a great many external factors influence infection this view was dis-

[10] Barrus, M. F. Variation of varieties of beans in their susceptibility to anthracnose. Phytopath. **1**: 190–195. 1911.

[11] *A* and *F* are the letters used by Doctor Barrus to designate the two distinct strains of *Colletotrichum lindemuthianum* so they are retained here.

carded. It is natural, too, for infection to occur to a small extent upon the resistant plants, since the Well's Red Kidney, the resistant parent, frequently is slightly susceptible to strain F of the anthracnose fungus. In table 1 are given the data concerning these F_2 individuals.

The pedigree number Misc. is a collection of 16 seeds from several plants which shelled while in the field. They were found on the ground and since it could not be determined from which plants they originated they were placed in a class by themselves. From the above table it will be noted that when those seed which failed to germinate are subtracted from the total number an extremely close approximation to a 3:1 ratio is obtained.

	RESISTANT	SUSCEPTIBLE
Observed number	362	111
Calculated number	354.75	118.25
	+7.25	−7.25

In obtaining a simple ratio, as 3:1, with resistance dominant it was apparent that only one strain of the anthracnose fungus was involved in the experiment, otherwise it would be reasonable to expect that segregation would be more complex. To determine this, eight White Marrow plants were selected. Four were inoculated with strain A and four with strain F of the anthracnose fungus. The latter became very severely diseased while those inoculated with strain A showed no infection. Moreover Doctor Barrus has informed the writer that the White Marrow is resistant to one strain of *Colletotrichum lindemuthianum*. This would account for a 3:1 ratio in so far as the experiment involved the character of resistance to only one strain of the pathogene. It also appears from this that the character is governed by a single factor. Some question, however, might arise as to this point since it was not proved that the parents of the hybrids were pure lines. On the other hand the constancy with which varieties of beans are either resistant or susceptible to the two strains of the fungus leads to the belief that pure lines were used in so far as the character of resistance was concerned. Furthermore, it is not a general occurrence for beans to be crossed in the field as self pollination takes place before the blossom opens.

Further breeding would throw light on this matter, but since it was the purpose of the writer to produce an anthracnose-resistant bean in as short a time as possible, detailed data were not taken after the F_2 generation. All susceptible plants were discarded. Likewise those plants which did not possess desirable characters, and those which would not produce

such on further segregation, were dropped from the experiment. The genetical constitution of such plants can be determined with certainty from the work of Emerson[12] on the behavior of determinate and indeterminate growth and of seed color in the bean. On the other hand all those plants which conformed to the commercial type of the White Marrow were saved to test for anthracnose resistance and to propagate as rapidly as possible. Under these conditions it was difficult to keep any reliable data concerning the behavior of the disease resistance after the F_2 generation.

Besides the White Marrow, three other commercial, but less important, varieties of beans were produced in the cross. They were the Vineless Marrow, the Red Marrow, and the White Kidney. Anthracnose-resistant strains among these varieties are being isolated, but the work has not progressed as rapidly as with the White Marrow. In this variety several families have been obtained which are homozygous not only for the anthracnose resistance, but for the characters of the White Marrow type. The work of selection has been hindered somewhat by the fact that resistance is a dominant character. Thus a large amount of careful inoculation work has been required to determine whether the character is homozygous. Two and sometimes three generations are being grown each year so that as rapid progress as possible is being made. The plants too are as promising under field conditions as under greenhouse conditions, and have proved to be very productive. The problem from now on is principally one of propagation, but some years must elapse before sufficient seed will be available for growers.

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[12] Emerson, R. A. Heredity in bean hybrids. Ann. Rept. Nebraska Agr. Exp. Sta. **17**: 36–68. 1904.

A genetic study of plant height in Phaseolus vulgaris. Nebraska Agr. Exp. Sta. Research Bul. **7**: 1–73. 1916.

EXCLUSION LEGISLATION AND FRUIT TREE PRODUCTION

V. B. Stewart

In a recent article, Galloway[1] outlines some of the important phytopathological problems in connection with the Office of Foreign Seed and Plant Introduction. This office is helping to build up American agriculture by introducing into this country many kinds of seeds and plants from widely scattered regions of the earth; is growing, testing, propagating and distributing these plants at five field stations: and is having the material grown by several thousand coöperators and collaborators. The importance of this work is well recognized and many of the problems involved are of direct interest to the plant pathologist since numerous plants which may be introduced are hosts for important parasites. This not only applies to new plant introductions but also to the wholesale commercial importations. In view of the recent agitation for the exclusion of all wholesale importations of live plants there appears to be need for a broader application of the plant testing enterprise, with a special study directed toward the successful growing in this country of many plants that are now being imported. With well established industries requiring large importations of living plants annually it appears unwise to prohibit such importations unless the same product can be produced successfully at home.

Some attention has been given to growing Holland bulbs in this country and forest tree seedlings are now successfully grown in America, but at the present time the nurserymen and florists of the United States are dependent upon many kinds of foreign-grown seedlings and bulbs. The attempts to produce these products on a commercial scale here have not been highly successful and when trials have been made, usually the plants were inferior to foreign-grown stock. This applies particularly to rose and fruit tree seedlings. The writer was recently impressed by the scarcity of good American seedlings when an attempt was made to obtain about thirty thousand each of several kinds of domestic-grown fruit tree seedlings for an experiment. One of the leading fruit seedling growers who is familiar with the industry made an effort to purchase the seedlings in the market. Apples could be obtained in abundance, but a sufficient

[1] Galloway, B. T. Some of the broader phytopathological problems in their reation to foreign seed and plant introduction. Phytopath. **8**: 87–97. 1918.

number of pear seedlings could not be found. With respect to the cherry and plum seedlings which were purchased, the seedling grower stated that "the Mahaleb cherry seedlings were grown in Kansas and were damaged some in the tops by a hard freeze early in October. The Myrobalan plums were grown in California, and I understand they had to dig them with spades out of dry hard soil. As a result they were poorly dug and the roots were cut rather short. Also the seedlings were damaged some either by frost or exposure in handling. I am sorry the stocks were not in better condition, but it was the best we could do. We only found one lot of Myrobalan seedlings."

There are numerous difficulties involved in the production of fruit tree seedlings in the United States and it can be definitely stated that nurserymen use foreign fruit seedlings, not only because the domestic supply is insufficient but mainly because long years of experience have convinced them that the foreign plants are superior and produce better budded nursery trees. In some instances the idea has prevailed that foreign fruit seedlings were preferred because they cost less. This is entirely erroneous because the nurserymen are importing French seedlings at a higher cost than that paid for American grown seedlings.

Repeated comparisons have demonstrated that it pays to secure the more expensive foreign stock and numerous instances have been observed by the writer of a difference in growth of American and foreign seedlings growing side by side in various Eastern nurseries. In cooperation with nurserymen the writer has supervised the planting of foreign-grown and domestic stock in adjoining rows and by midsummer the foreign seedlings could easily be distinguished by their superior appearance. Furthermore when these seedlings were budded and a careful count made of the trees two years later it was found that the foreign seedlings had produced a higher percentage of first class trees.

Oftentimes there appears to be no difference between the foreign and domestic seedlings before they are planted in the nursery row but evidently the foreign stock establishes itself more readily and thus displays a more vigorous growth. In Europe the seedlings are grown in small beds and are given individual attention while the usual practice in America is to plant the seed in rows as in case of other nursery stock. It is also customary for the European growers to transplant the seedlings and this causes a much branched root system, while American seedlings are not transplanted and have long straight roots. For budding purposes the seedling with the branched roots is preferred. This kind of a root system may also account for the apparent increased vigor of the foreign stock after it is set in the nursery.

There are other difficulties involved in the production of fruit seedlings in this country, one of them being the fact that with the exception of a small amount of apple, pear and Mazzard cherry seed, the seedling growers are dependent upon foreign seed. There is one large Myrobalan plum orchard in California maintained for its seed production, but the supply obtained is only sufficient for the nurserymen who own the orchard. In the state of Kansas where apple and pear seedlings are grown the success of the industry is dependent primarily upon the growers' ability to obtain seed from foreign lands. In California and Oregon, plum and cherry seedlings have been grown, but great difficulty has been experienced in getting seed that will germinate satisfactorily and at the proper time.

By the time seed are collected in Europe, shipped here and then forwarded to destination, which is mainly in the middle West and Pacific coast region, the seeds become so dry that they lose their power of germination. It also frequently happens that when seed is in fine condition for planting, after being stratified in sand, it is placed in the seedling beds or nursery rows and under conditions of rains or continued cloudy weather the seed rots. Attempts to retard germination by removing the stratified seed to a cold storage have not proved satisfactory.

The crown gall disease caused by *Bacterium tumefaciens* Smith & Towns, has proved also a limiting factor in seedling production in these states. Frequently when the seedlings are dug for market a large proportion are rejected on account of infections by this organism. Apparently the foreign growers are not seriously troubled with these losses. A member of the Franco-American Seedling Company estimates that the percentage of seedling stock destroyed in France each year on account of diseases or insect pests does not exceed 1 per cent of the crop.

It is reasonable to assume that proper environmental conditions can be found in America for growing seedling nursery stock that will possess the vigor of foreign seedlings. However, the lack of a sufficient domestic seed supply would still be an important consideration. Most nurserymen agree that if orchards were planted in America of Mahaleb cherry, Myrobalan plum, French Crab apple, and the like, so that the crop of seed could be gathered and cured early and the nurserymen get the seeds while they were still fresh, one of the great difficulties would be obviated. It will no doubt require considerable experimentation to determine the conditions, such as proper soil and climate, that are most conducive to seedling production. In the meantime, who will assume the responsibility of developing the seedling orchards? This will take many years and it means large investments in these orchards until such time as they produce a good crop of seeds; and these seedling trees do not begin

fruiting as early as grafted trees. Most growers hesitate to make such an uncertain investment.

The above-mentioned conditions are some of the obstacles to be encountered if a law is enacted prohibiting the wholesale importation of all live plants now classed as nursery stock. It could only result in a curtailment of certain phases of agriculture until scientific experimentation in America has determined a means of producing all of these raw materials. Although the solution of such a problem may not lie within the field of plant pathology it must be considered by the pathologist when advocating a plant exclusion act.

It may even be questioned as to whether the prohibition of such stock is necessary as a means of preventing the introduction of most parasites. It is a question whether the diseases and pests of all agricultural plants have not been introduced repeatedly during the long period of free interchange of such materials. However, in case of the more recent activities in introducing new and little known plants and especially tropical and subtropical forms coming from regions where a knowledge of these parasites is meager, restrictive measures may not be out of place.

It is well to be cautious and to advocate restrictive measures in cases of doubt but precaution also should be taken to provide for obstacles which may arise as a result of such methods of preventing the spread of plant diseases and insect pests. It is perfectly evident that if such measures fail in accomplishing the desired end it is the agriculturist and general public that bear the financial losses; the pathologist only loses the confidence of the grower; and owing to the failures of certain domestic quarantines the peoples' respect for prohibitive measures is none too great at the present time.

From the point of view of public policy with respect to legislation that places an embargo on plants which are now being imported, Prof. L. H. Bailey is the authority for the following statement: "I fear the domination of small groups of men who may control commerce and set burdensome limits to the action of responsible citizens. I also fear the international results of such interference and the setting up of the obstacles to proper understanding among the peoples of the earth. I am in sympathy with quarantines but not with embargoes except as measures of war or of crisis. I judge that no crisis is now confronting us. We cannot slam our doors in the face of other peoples and then expect them to open their doors to us. Eventually this will become a question of statesmenship and diplomacy as well as of agriculture."

In conclusion it is well to point out that all phases of the nursery industry are specialized enterprises which serve as feeders in furnishing the raw materials to many branches of agriculture. In any project which is

for the betterment of American agriculture whether it be by quarantine legislation or otherwise it is desirable that the raw materials be of as high quality as possible. Phytopathology as well as other agricultural sciences has given comparatively little attention to the many problems confronting the nurserymen; the time should soon come when the present police inspector will have the same relation to the nurseryman as the county agent who aids the farmer in improving his crops. Along with the police duties of the scientifically trained specialists their most valuable function would be to coöperate with the nurseryman, encouraging methods for improving crop production as well as controlling plant diseases and insect pests. It is needless to state such a coöperation would be heartily welcomed by the nurserymen.

DISSEMINATION OF SEPTORIA LYCOPERSICI SPEG. BY INSECTS AND PICKERS

W. H. Martin

In connection with experiments conducted during the summer of 1917 for the control of tomato leaf spot, studies were made to determine the methods of dissemination of the causal organism (*Septoria lycopersici*). Insects and pickers were considered as possible factors in distribution and an effort was made to determine to what extent they were carriers of the spores.

An extensive literature has accumulated on the dissemination of fungous spores by insects. In some instances the evidence advanced is contradictory and the importance attached to this method of spore dissemination may have been over-estimated. The literature on this subject has recently been reviewed by Studhalter and Ruggles (4) so that no mention of previous investigators need be made here.

INSECTS AS CARRIERS

In New Jersey the tomato is visited by Colorado potato beetles (*Leptinotarsa decemlineata* Say) and their larvae; flea beetles (*Epitrix cucumeris*, Harris); tomato worms, (*Protoparce carolina* Linn.); and plant lice (*Aphis pseudolrassical* Davis), in large numbers; the first of these sometimes becoming so abundant as to necessitate spraying with an insecticide for their control. All four of these insects are present until late in the season so that it would appear that many of the plants in a field are visited at some time during the growing season.

Observations made during the summer indicate that early blight (*Alternaria solani*) of tomatoes is disseminated by flea beetles, numerous instances being observed where flea beetle punctures were the center of an early blight infection. It cannot be concluded from this that spores were deposited on the leaf by the insect for it is possible that injury to the leaf made conditions favorable for infection, which was brought about by wind carried spores. From the large number of cases noted, however, the evidence indicates infection by the beetles.

In this work two methods of procedure were employed; (1) insects and excreta were collected directly from plants in the field and examined for

spores, and (2) insects were collected and allowed to feed on diseased leaves in a moist chamber for a definite period before an examination was made.

INSECTS COLLECTED FROM PLANTS IN THE FIELD

These insects were collected from diseased and healthy plant parts at various times during the growing season. They were removed from the plant by means of a pair of sterile forceps and placed in small vials in which they were taken to the laboratory and examined for the presence of spores.

The method for removing the adhering spores was as follows: a drop of sterile water was placed on a slide and the insect to be examined was held in it by means of a pair of sterile forceps. The movement of the insect in an effort to escape was enough to remove the spores. This is in accordance with the findings of Studhalter and Ruggles (4) who demonstrated that spores of the chestnut blight fungus were easily shaken from the body of the beetle (*Leptostylus macula*) by its own movements.

Examination of insects collected early in the season showed no spores. As the season advanced, however, and the disease became more prevalent, all insects examined were found to carry spores whether taken from diseased or healthy leaves.

The results of these tests are given in table 1.

TABLE 1

Examination of insects collected in the field

INSECT	DATE COLLECTED	NUMBER OF SPORES	
		S. lycopersici	A. solani
Larva of Colorado potato beetle	July 23	25	10
	July 23	24	4
	July 23	36	0
	August 7	10	0
	August 7	60	90
Tomato worm, P. Carolina, Linn	August 7	90	7
	August 7	106	6
	August 7	36	13
	August 7	80	16
Colorado potato beetle (adult) L. decemlineata Say	August 17	160	11
	August 17	27	0
	August 17	225	2
	August 17	200	2
	August 17	100	5
	August 17	190	4

Germinating spores of both *A. solani* and *S. lycopersici* were removed from insects that had been collected early in the morning when there was moisture present on the leaf. Under favorable conditions such as these the spores might have germinated on the leaf before becoming attached to the insects or germination may have taken place on the insect itself.

INSECT EXCRETA FROM PLANTS IN THE FIELD

This material was collected from leaves and stems free from disease in order to avoid removing spores from the diseased areas and thus greatly increasing the spore count. The deposits were removed by means of a sterile scalpel and placed in vials. A portion of this material was macerated in water and examined under the microscope. The excessive amount of undigested plant tissues present made the counting difficult and the results uncertain so that the number of spores in the material could only be approximated.

TABLE 2

Number of spores observed in the insect excreta collected from plants in the field

DATE OF COLLECTION	NUMBER OF SPORES	
	S. lycopersici	A. solani
July 23	24	0
July 23	7	0
July 23	34	0
August 6	7	4
August 6	10	3
August 16	40	0
August 16	30	1
August 16	25	0

In table 2 is given the number of spores in the fecal deposits examined. While the number noted is in no case large yet the results clearly indicate that the spores are carried in this manner. Instances were noted where both the *S. lycopersici* and *A. solani* spores were germinating, indicating that alimentation does not destroy their viability.

The fact that the excreted spores are viable is very important. It is probable that by this method the spores are distributed over a wide area, whereas when borne on the body of insects they are carried only short distances.

INSECTS FROM MOIST CHAMBERS

Tomato leaves heavily infected with late blight and early blight were placed in moist chambers together with insects. These insects were

allowed to feed over night and were then removed and examined for spores. The method employed in this examination was the same as that for insects collected in the field.

The results of the examination are given in table 3.

TABLE 3

Number of spores from insects kept in moist chambers with diseased plants

INSECT	NUMBER OF SPORES	
	S. lycopersici	A. solani
Larva of Colorado potato beetle	10	0
	100	0
	150	0
	100	4
	70	3
	21	0
	65	7
	100	5
	200	0
	250	3
	150	0
Tomato worm P. carolina Linn	75	10
	100	10
	75	0
	50	5
Lady-bud beetle C. novemnotata Host	250	0
	70	0
	50	5
Colorado potato beetle, L. decemlineata, Say (adult)	75	0
	30	0
	60	4
	40	1
	39	4
	42	10
	29	0
	21	0
	75	0
	22	4
	19	6

All the insects examined were found to carry spores, as many as 250 being found on a single individual. Tomato worms were found to carry large numbers of spores. In several instances, after the first examination was made, the worms were washed a second time revealing the presence of

spores not removed in the first washing. It is doubtful whether this insect plays an important rôle in dissemination, however; since they are not usually present in large numbers and the individual does not travel far.

EXCRETA FROM INSECTS ALLOWED TO FEED ON DISEASED LEAVES IN MOIST CHAMBERS

Excreta from insects allowed to feed on diseased leaves in moist chambers were found to contain large numbers of spores. The leaves on which the insects were allowed to feed were so heavily infected that it was impossible to collect excreta from uninfected areas. To avoid the error which would arise from removing some of the spore mass along with the fecal deposit a different method than that followed in the field was employed. An insect was removed from the diseased material and after being thoroughly washed was placed on a glass slide where the fecal material was caused to be deposited by applying pressure on the abdomen of the insect with a pair of sterile forceps. In this way no spores, other than those in the deposits, were taken.

The results of the examination are given in table 4.

TABLE 4

Number of spores observed in excreta from insects taken from diseased leaves in moist chambers

DATE OF OBSERVATION	NUMBER OF SPORES	
	S. lycopersici	A. solani
July 19	45	0
July 19	40	0
July 19	16	0
August 7	28	2
August 7	39	1
August 7	12	4
August 7	19	0
August 7	150	0
August 7	40	0
August 7	30	1
August 7	19	0
August 7	10	0

The results of these examinations and those made of the fecal deposits collected from plants in the field indicate, beyond a doubt, that the insects feed on the diseased leaves. It is not supposed, however, that they fed on the diseased leaves in preference to the healthy leaves. Craighead (2) has shown that the beetle *Leptostylus macula* Say feeds on the

pustules of the chestnut blight fungus. Gravatt and Marshall (3) likewise note that a small slug was observed feeding on the telial columns of *Cronartium ribicola* and a sow bug was observed eating out pycnial pustules and the surrounding tissue of the blister rust swellings.

The results of these experiments demonstrate that *Septoria lycopersici* and *Alternaria solani* spores are not only carried on the bodies of insects but in the digestive tract as well and that the excreted spores are viable. It is believed, however, that too much importance should not be attached to insects as factors in the distribution of leaf spot. While the larvae of the Colorado potato beetle were found to carry large numbers of spores, it is doubtful whether they are of importance except in carrying the disease to different parts of the same or neighboring plants. The mature beetles may, however, visit a large number of plants and, therefore, more importance may be attached to them as carriers. The facts at hand lead to the conclusion that these beetles function in the early distribution of the disease and in this respect are of considerable importance.

PICKERS AS FACTORS IN THE DISSEMINATION OF SPORES

It is frequently stated, but usually without experimental evidence, that man is a factor of considerable importance in the distribution of some plant diseases in that he may carry spores from a diseased to a healthy plant by contact. Whetzel (5) expresses the belief that the spores of bean anthracnose are distributed through cultivation and by pickers. Butler (1) states that in India, the Godaveri palm disease is frequently carried by the men who climb the trees. A review of the literature revealed little evidence of a direct nature on the question of dissemination of fungi by this means.

The following experiments were performed to demonstrate this point. The method employed was to remove the adhering material from the hands and garments of the pickers by scraping with a scalpel. The material was placed in glass vials and after the addition of a small quantity of water was examined, a drop at a time, for spores.

Table 5 gives the results of these examinations.

This material was collected from two different sources, in one case the pickers had just finished picking in a field where there was little blight present. The other material was taken from pickers at work in a field in which the plants were severely diseased. In every case the material to be examined was collected when there was little moisture on the plants so that it is to be expected that had the plants been wet, the spore count would have been considerably higher.

Comparatively few spores were found in the material from the field in which the plants were only slightly infected, while large numbers were obtained from the field where the plants were severely infected. The number of spores removed from the hands was considerably greater than from the garments. This may be explained by the fact that in picking tomatoes it is necessary to turn over many of the vines in order to reach the fruit.

The results of these tests are rather striking in that they appear to throw considerable light on the question of the dissemination of late blight. It is a matter of common observation in New Jersey that this disease becomes especially severe after the second picking. In view of the fact that the picking dates are usually a week apart, and that a period of approximately ten days elapses before the disease becomes apparent, it would appear that this sudden increase in the amount of disease present may be traced to the first picking. In moving the vines the pickers come in contact with the diseased leaves, the sticky spores adhere to their hands and in this way are carried to other plants.

TABLE 5

Number of spores observed in material scraped from pickers' hands and garments

SOURCE OF MATERIAL	NUMBER OF DROPS EXAMINED	NUMBER OF SPORES	
		S. lycopersici	A. solani
Hands (plants slightly infected)	6	17	43
Garments (plants slightly infected)	7	3	12
Hands (plants severely diseased)	10	692	17
Hands (plants severely diseased)	10	480	50
Garments (plants severely diseased)	10	50	3

These results should emphasize the fact that picking should be delayed after a rain or heavy dew until the plants are dry. When the leaves are wet the spores are readily carried and, at the same time, are readily deposited on other leaves where the moisture present affords a condition highly favorable for germination and infection. It may not always be possible to defer late pickings until the plants are dry but in the early season, when the plants have yet to set a large part of their fruit, it would be well to wait so as to prevent, so far as possible, the dissemination of the fungus.

SUMMARY

1. The insects examined were found to be carriers of *Septoria lycopersici* and *Alternaria solani* spores.

2. Alimentation has little effect on the viability of the spores.

3. Insects are important factors in the early distribution of the disease.

4. Pickers were found to carry large numbers of *Septoria lycopersici* spores on their hands and garments. They are important factors in the dissemination of this organism.

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REVIEWS

Palladin's Plant Physiology. Authorized English edition, edited by Burton Edward Livingston. xix+ 320 pp., 173 illustrations. Published by P. Blakiston's Son & Co., Philadelphia, 1918.

Plant pathologists who are more interested in pathology and the basic science, physiology, than in mycology and bacteriology will welcome an English edition of Palladin's well-known book. It will be of interest to teacher and investigator alike as a ready book of reference. Two-thirds of the book is devoted to the physiology of nutrition, the phase of physiology of greatest interest to the pathologist.

There are so many commendable things about the make up of the English edition that prospective authors would do well to consult it for style. The text is said to be a "true translation" of the German edition but it is put into exceedingly readable English; the editor explains fully the form of citation employed; the citations are consistent throughout and conform to best American practice; a standard method of transliterating is adopted and adhered to; the index is very complete; the editor makes intelligent use of the mechanical means available to the high-class publisher of making conspicuous the various kinds of catch-words so convenient in a work of reference.

The book deserves to be referred to as the Palladin-Livingston Physiology. Aside from the fact that Livingston is editor, there is scarcely a page that does not bear "editorial notes." While it is true, as the editor states, that "they constitute, in the aggregate, only a small portion of the volume," nevertheless they form a very valuable addition in that they are critical and in that reference is made to literature not noted by Palladin.

The editor deserves commendation and Mrs. Livingston our warmest thanks for correcting, completing, verifying and standardizing the citations to literature throughout.

The book is well made, of handy size (16 by 24 cm.) and printed in clear ten-point type. The only objectionable feature is the glossy paper, used apparently to allow satisfactory reproduction of a few half-tones.

DONALD REDDICK

PHYTOPATHOLOGICAL NOTES

Deferred draft classification for plant pathologists. There is an increasing recognition of the great need for the services of all available plant pathologists in the national and state campaigns for increased food production. In most cases the local draft boards are now granting deferred classification under the draft where requests are made by men trained for such service. Since it is, however, necessary in some cases to make special appeal for this, or to secure the transfer of men already in military service through their discharge, furloughing, or detailment for plant pathological service, the following were named a committee at the recent meetings of Plant Pathologists War Board Conferences to pass upon and advise in such cases as requested: F. D. Kern, E. M. Freeman, E. P. Meinecke, L. R. Jones (Chairman).

This committee is presenting its requests for deferred classification in cases deemed so deserving through Dr. J. M. Coulter, as Chairman of the Botanical Committee of the National Research Council, in coöperation with Dr. Vernon Kellogg. Dr. Kellogg sends the Committee the following instruction with the request that it be given as wide publicity as practicable.

"It should be made widely known that wherever deferred classification for scientific men is asked for, it is necessary to take up the matter first with the Local Boards. If the Local Boards will not give the desired relief then appeal must be made within five days after the mailing of notice of the classification given. If this appeal is not made, it makes it very much more difficult to take up the matter later. As a matter of fact the regulations authorize the Local Boards to give a deferred classification to any necessary highly specialized agriculture expert employed by a state agricultural college or by any known department, when this expert is found to be necessary to agriculture as an industry and necessary to the adequate and effective operation of the service in which he is engaged and when he cannot be replaced without substantial material loss and detriment to the adequate and effective operation thereof. As a matter of fact I think that this provision will apply also to men engaged either under salary or as volunteers in work of the Council of National Defense. As the National Research Council is acting at present as a department of the Council of National Defense, men engaged in the investigations for the National Research Council should come under this provision. But

in all cases the attempt to get a deferred classification for such men should be begun before the Local Boards."

Personals. The Office of Fruit Disease Investigations, Bureau of Plant Industry, has recently added the following pathological workers to its staff: For work in coöperation with the Bureau of Markets on the inspection of carload lots of fruits at terminal markets and the identification of diseases affecting such shipments, Mr. B. O. Dodge, formerly an instructor at Columbia University, Mr. H. D. Hendricks, of Anderson, Indiana, and Mr. John G. Hall; for work on the diseases of small fruits, Miss Grace A. Dunn, of Lake Erie College, Ohio, Mr. W. H. Sawyer, Jr., of Lewiston, Maine, and Mr. Arthur N. Wilcox, of Wisconsin University; for work on pecan diseases, Mr. J. B. Demaree, formerly with the State Board of Entomology of Indiana; and for general work on fruit diseases, Prof. A. H. Chivers, formerly assistant professor of botany at Dartmouth College, New Hampshire.

The Office of Cotton, Truck, and Forage Crop Disease Investigations, Bureau of Plant Industry, has recently appointed Mr. Wm. S. Porte, of Rutgers College, New Jersey, as scientific assistant in plant pathology, to assist in tomato spraying experiments; Mr. S. L. Dodd, Jr., formerly with the West Virginia State Crop Pest Commission and Agricultural Experiment Station, as extension pathologist in the state of West Virginia, with headquarters at Morgantown; and Mr. G. M. Armstrong, instructor in plant pathology at Clemson College, South Carolina, as extension pathologist in the state of Alabama, with headquarters at Auburn; Mr. C. S. Ridgway, of the Bureau of Plant Industry, has been transferred from assistant in tobacco disease investigations to the position of extension pathologist in the state of Maryland, and Mr. D. C. Neal has been transferred from the citrous disease investigations of the Bureau of Plant Industry to the leadership of the pathological extension work in Louisiana, with headquarters at Baton Rouge.

LITERATURE ON PLANT DISEASES[1]

COMPILED BY EUNICE R. OBERLY, LIBRARIAN, BUREAU OF PLANT INDUSTRY, AND FLORENCE P. SMITH, ASSISTANT

April, 1918

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[1] This list includes references, both American and foreign, to the literature of plant pathology and mycology of interest to pathologists. Foreign references published since January 1, 1917, have been included beginning with the list appearing in v. 7, no. 3, June, 1917.

All authors are urged to coöperate in making the list complete by sending their separates and by making corrections and additions, and especially by calling attention to meritorious articles published outside of regular journals. Reprints of correspondence should be addressed to Miss E. R. Oberly, Librarian, Bureau of Plant Industry, U. S. Dept. Agri., Washington, D. C.

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